DEPARTMENT OF THE INTERIOR, CANADA
HON. CHARLES STEWART Minister W. W. CORY, Deputy Minister
GEODETIC SURVEY OF CANADA
NOEL OGILVIE, Director

ANNUAL REPORT

OF THE DIRECTOR

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDING MARCH 31, 1924

1923/24

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1924

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CONTENTS

HALF TONES

82407—1½

HALF-TONES—(*Continued.*)

PLATES

MAP

ANNUAL REPORT OF THE DIRECTOR

OF THE

GEODETIC SURVEY OF CANADA

SIR,—I have the honour to submit my seventh annual report as Director of the Geodetic Survey of Canada, for the fiscal year ending March 31, 1924.

RÉSUMÉ OF OPERATIONS

Geodetic Survey operations were carried out in eight of the nine provinces during the field season of 1923. The following table shows the districts in which the field work was carried on:—

Province	District	Operations
Nova Scotia	Northern Cape Breton	Primary Triangulation
	" " "	Base Line Measurement
	" " "	Geodetic Astronomy
New Brunswick	St. John River Valley	Precise Levelling
	Bay of Chaleur	Primary Triangulation
	" " "	Base Line Measurement
	" " "	Geodetic Astronomy
Quebec	Hamilton Inlet	Precise Levelling
	Eastern Townships	Precise Levelling
	Northern Quebec	Precise Levelling
	Northern Quebec	Geodetic Astronomy
	Gulf of St. Lawrence	Primary Triangulation
	Bay of Chaleur	Primary Triangulation
	Lower Saguenay River	Primary Triangulation
	Northern Quebec	Secondary Triangulation
	City of Quebec	Secondary Triangulation
	City of Quebec	Precise Levelling
Quebec and Ontario	Ottawa River	Primary Triangulation
Ontario	City of London	City Mapping
	Sioux Lookout Vicinity	Precise Levelling
	Minden Vicinity	Secondary Triangulation
Manitoba	Winnipeg Vicinity	Precise Levelling
	49th Parallel	Primary Triangulation
Saskatchewan	49th Parallel	Primary Triangulation
Alberta and British Columbia	British Columbia-Alberta Boundary	Secondary Triangulation
British Columbia	Northern British Columbia Coast	Primary Triangulation

In the above list two points are to be noted:—

1. Operations in more than one district were in some cases carried on by one party, where the work to be accomplished in one district did not occupy the whole season. For example, the base-line measurement in Nova Scotia and New Brunswick, and the geodetic astronomy in Nova Scotia, New Brunswick and northern Quebec, were each done by the one party. Several similar cases occur in the above list.

2. Operations in one district were in some cases accompanied by several parties. For example, the name primary triangulation comprises the following operations: reconnaissance, tower building, station preparation, angle measurement, etc., each carried on by a separate party. All or only one of these operations may have been carried on where primary triangulation is the operation specified.

Precise Levelling

During the fiscal year, ending March 31, 1924, the long line of precise levels across northern Ontario and Quebec was advanced another stage. This line was started in 1920 near Rennie, Man., and has followed the main (transcontinental) line of the Canadian National railway, the 1923 work being eastward from Cochrane, Ont. Having reached Oskelaneo River, Que., at the close of the field season, it is expected that the fiscal year 1924-25 will see the termination of this line at Three Rivers.

In New Brunswick the line of levels following the St. John River valley, which had previously been completed from the city of St. John as far as Gagetown, was continued up the course of the river to Woodstock; as levels north of Woodstock had been completed several years ago, we now have a continuous line of precise levels following the valley of this important river from the town of Edmundston to the river's mouth at the city of St. John.

Two or three comparatively short lines in the Eastern Townships of Quebec—amongst the first lines to be run by this Survey—were relevelled during 1923, partly in order to improve the accuracy of the levelling and partly to provide a sufficient supply of permanent bench-marks to give the requisite detail control in the district, many of the original bench-marks having been destroyed in the lapse of time since the first levelling. It is planned to have a party continue this work in the next fiscal year.

In the city of Quebec and surrounding district a large number of bench-marks were established at the request of the city authorities and at the city's expense, this work being an extension and development of the levelling carried out under similar conditions in the fall of 1922.

No levelling operations were in progress west of Winnipeg; however, a line was run from Winnipeg northerly to Victoria Beach, Man., and another from Superior Junction, Ont., to a point near Fort William.

A special line of levels (not connected with the general net) was also run, in response to a request from the Department of Justice, between Hamilton inlet and lake Melville, on the Labrador coast, this work being carried out in co-operation with the Hydrographic Survey of the Department of Marine.

An interesting innovation in the 1923 levelling was the introduction of a new type of levelling rod to replace the paraffin-treated wooden rods used heretofore. In the new rods the graduations, in place of being painted on the wood, are carried on a strip of invar secured solidly to the metal foot-block and attached to the face of the rod in such a manner as not to be subjected to strain by any expansion or contraction which may take place in the wood. Since invar is unaffected either by moisture or by variations of temperature such as are found under field conditions every confidence may be had in the accuracy of differences of elevation determined by these rods. Their use, which is in accordance with the best modern practice of levelling of precision, had been decided upon some time ago, but owing to difficulty in securing the invar strips, considerable delay ensued and it was only at the beginning of the 1923 field season that it was possible to place the new rods in use.

Triangulation

In general the season of 1923 was the most productive of primary triangulation results of any season for a number of years, being in marked contrast with the summer of 1922, when the weather was probably the most unfavourable for primary triangulation for several years. In particular in the gulf of St. Lawrence and the 49th parallel areas the results accomplished were most gratifying. The angle measurement party on the 49th parallel primary triangulation created what is believed to be a world's monthly record for low cost of this class of work. A few details of the work accomplished are as follows:—

11 primary stations completed,
2 supplementary stations completed,
9 nights lost through bad weather, moving camp or Sundays, leaving
22 days for actual operations.

This party had only one lightkeeper; a light motor car was used for moving the signal lamps, which were equipped with time switches. The party was, hence, composed of only four men, engineer, recorder, lightkeeper and cook.

Nova Scotia.—The east coast of northern Cape Breton island was the scene of primary triangulation operations in this province, although a few stations in other parts of the province were re-marked with permanent concrete monuments.

Triangulation was completed to the northern end of the island, also part of the triangulation connection between Cape Breton island and Newfoundland. Further details of this work are given on page 39, while a sketch showing the work completed appears on page 40.

This will complete the primary triangulation in this section of Nova Scotia.

New Brunswick.—Two alternative base-nets were selected in the bay of Chaleur area, the best base-line being measured later in the season.

Tower building operations in the same vicinity and southward along the east coast of New Brunswick in preparation for direction measurements in 1924 comprised the remaining triangulation work in this vicinity.

Secondary triangulation in the vicinity of Sussex, N.B., was carried on as a control basis for the Topographical Surveys.

Quebec.—Triangulation was carried on in three main areas during 1923—the gulf of St. Lawrence, the area south of lake St. John, and the Ottawa river above Ottawa. In addition, a small amount of secondary triangulation was completed in the vicinity of the city of Quebec, together with the tower building in the bay of Chaleur area mentioned above.

Operations on the gulf of St. Lawrence during 1923 completed the primary triangulation as far east as Gaspé on the south shore mainland and southwest point on Anticosti island, also about half-way along Anticosti island on the north channel. These points are as far east as triangulation can be obtained on Anticosti island. Triangulation further east along the northern side of the gulf must be carried along the north shore exclusively. During the summer of 1923 and the following winter reconnaissance for the selection of stations proceeded about 125 miles ahead of the angular measurement to the vicinity of Wolf bay in longitude 60 degrees. The sketch shown on page 35 shows the progress of the completed triangulation in this area. The reconnaissance is not completely shown on this sketch.

At the start of the 1923 season the gulf of St. Lawrence parties completed the angular measures on the lower Saguenay river to connect the St. Lawrence net with the secondary triangulation scheme on the upper Saguenay area. The season's progress of the St. Lawrence parties was large on account of the favourable weather. For fuller information on the operations in these areas see page 34.

The secondary triangulation loop up the Saguenay river to lake St. John was continued during 1923 southward in a belt along the railway from lake St. John to Quebec, a point near lake Edward being reached by the fall. Forest fires in the St. Maurice valley to the westward delayed these operations, since north and west winds which ordinarily bring clear weather, in this case brought only smoke. This net is of great importance geographically, as very many base lines, county lines and control points of the provincial land survey system have been accurately located by the triangulation, and the effect will be felt for many miles on both sides of the net, in the more accurate mapping of the country. For a sketch of the triangulation in this area see page 33, while further details of the operations begin on page 32.

On the Ottawa river angular measurements on the primary triangulation net were carried almost as far west as Pembroke. The experiment was tried in this area of having the angular measures made by a party of two men only, engineer and recorder. The electric signal lamps were equipped with time switches and the two men with light cars moved their own lamps besides doing the instrumental work. This carried the work on very economically, but progress was not so fast as it would have been had a competent lightkeeper been added. The organization of angular measurement parties equipped with electric lamps and time switches will in future (in view of the experience of 1923), tend to be three or four men—engineer, recorder and cook, and in some cases a packer—for the instrumental work, and one or two lightkeeping units of one or two men each, depending on the ease or difficulties of transport. In any case the cost of angular measurements in primary triangulation can be very materially decreased. In this connection see page 11 of the Annual Report of the Geodetic Survey for the fiscal year ending March 31, 1923.

This net is a very important one as it will eventually extend up the Ottawa river and along the Temiskaming and Northern Ontario railway to James bay, with one branch to Sault Ste. Marie and Port Arthur and others eastward and westward into northern Quebec and Ontario. Further details of the work accomplished may be seen on page 32, while a sketch of the triangulation appears on page 38 of the annual report for the fiscal year ending March 31, 1923.

Triangulation operations near the city of Quebec were confined to a few small extensions to the net completed in the Quebec vicinity in 1922, which was described on pages 32 and 34 of the annual report for the fiscal year ending March 31, 1923.

Operations on the bay of Chaleur were described above under the heading of operations in New Brunswick.

Work on the gulf of St. Lawrence triangulation is being discontinued in 1924 except for a reconnaissance party, which will continue the selection of triangulation stations towards the straits of Belle Isle.

The secondary triangulation net north of Quebec city will be continued southward during 1924 and, it is hoped, will be connected to the primary scheme on the St. Lawrence river near Three Rivers.

Ontario.—Primary triangulation operations in Ontario during 1923 were confined to the Ottawa river area which is mentioned above under the heading of work in Quebec. The geographical value of this net in the well settled part of the area from Ottawa to Chalk River is great, as it ties in church spires, buildings in Petawawa reserve, angles of Algonquin park, and many points along the interprovincial boundary.

A small secondary triangulation net was completed during 1923 in the vicinity of Minden, Ont., in co-operation with the University of Toronto, to supply triangulation to the vicinity of the university's survey camp. The net was connected to the primary triangulation in that vicinity and provided num-

erous geographical positions in addition to those required for the immediate purpose of the net. Professor L. B. Stewart of the University of Toronto performed all of the field work in accordance with Geodetic Survey practice and also the adjustment and calculations in connection therewith, the Geodetic Survey providing only the field expenses of the operation and receiving the data for general use.

Manitoba and Saskatchewan.—Triangulation in these two provinces may be considered as a unit, as three inter-dependent parties were working on various stages of the co-operative scheme along the international boundary during the season of 1923. This net has been fully described in late annual reports of the Geodetic Survey.

During 1923 the western half of this net was completed, the angle measurements being finished as far east as Estevan, Sask., a total distance of 260 miles, of which 190 miles was completed in 1923. Reconnaissance for the selection of stations to lake of the Woods, together with a short spur to Camp Hughes near Brandon, was also completed and all stations prepared as far east as the Saskatchewan-Manitoba boundary.

Mention has already been made of the splendid progress which was made in this area and of the record which was established during 1923. Interesting data regarding this work is given on page 27.

British Columbia.—The secondary triangulation along the British Columbia-Alberta boundary from Yellowhead pass northward to Jarvis pass was continued during 1923. The selection and preparation of stations was completed and a start made on the angle measurement. It is anticipated that this work will be finished in 1924. For further details and sketches see page 24.

Along the northern British Columbia coast a connection was made between the triangulation which had been carried up from the south with that completed around Dixon entrance in 1913 and 1914. To this latter net the south-eastern Alaska triangulation of the United States Coast and Geodetic Survey is joined and a continuous net of primary triangulation now extends from California to Alaska. A fuller report of this work commences on page 22.

Survey Camp on the Robson pass, north of Jasper on the British Columbia-Alberta Boundary. Lake Adolphus and Low Foot hills skirting the Coleman Glacier.

A remarkable expanse of open country on the Sheep Creek Divide, north of Jasper, along the British Columbia-Alberta boundary.

Clouds settle over Triangulation Station on mountain top along British Columbia Coast. This condition is of frequent occurrence at certain seasons of the year and prevents angular measurements on an otherwise clear day.

Geodetic Astronomy

During the season of 1923 three stations of the triangulation were occupied as Laplace (coincident longitude, azimuth and triangulation) points, Sugar-Loaf on Cape Breton island, Campbellton in New Brunswick and Chicoutimi in northern Quebec. All of these stations were located on rugged hills to which it was impossible to transport the instruments except by horse or man-pack. The astronomical transit Cooke No. 2 used in determining field longitudes is a very heavy instrument and can be carried only by great exertion and expense. Steps are now being taken to secure a lighter and more suitable instrument for use in the field. In addition to the observations for longitude and azimuth the latitudes were also observed. As usual the exchange of time signals was made with the Dominion Observatory; this arrangement whereby the standard clock at the observatory is available for the determination of longitudes has added appreciably to the accuracy of the longitude determinations. Six Laplace stations will be required in 1924, one in the northern British Columbia net, two in the British Columbia-Alberta boundary net, two in the 49th parallel net and one in the Ottawa river net. The 1923 operations were all east of Ottawa; those of 1924 will all be west.

Base Lines

Two base-lines, one in Cape Breton and the other near the bay of Chaleur in New Brunswick, were measured during the summer of 1923. The one on the barrens of Cape Breton checked the scale of the triangulation of the eastern Nova Scotia net. All supplies and equipment were man-packed from Ingonish, a distance of over ten miles. The base itself was on the height of land in a very desolate part of the country. The ground was covered with moss, muskeg and stunted spruce and the measuring was more or less difficult. It is gratifying to be able to say that even under such conditions. the required accuracy was obtained. The bay of Chaleur base-line lies for the most part along the right of way of the Canadian National Railway and its preparation and measurements presented little or no difficulty.

In addition, two secondary bases will be required, one at the northern end of the British Columbia-Alberta boundary net and one on the lake St. John-St. Lawrence river net.

Standards

The five fifty-metre invar base-line tapes were standardized at three different times during the summer of 1923—before measuring the Cape Breton base-line, between the measurement of this base-line and that of the bay of Chaleur base, and finally after the latter base had been measured. The changes in the length of the several field tapes is most interesting. It was found that two of them lengthened during the summer, while a third had shortened. These changes emphasize the need of keeping a close check on the lengths of invar base-line tapes. Nickel bar No. 10239 is the standard, and all lengths depend directly on the length of this bar.

The new precise level rods with the strips of invar carrying the graduations referred to in my last annual report were completed and standardized. Three pairs were used in the field during the season of 1923 and gave every satisfaction. At the end of the field season they were again standardized and the change from spring to fall was less than the probable errors of standardization. They are a great improvement over the old wooden rods.

EFFECT OF WEATHER CONDITIONS AND LENGTH OF LINE ON PROGRESS OF ANGULAR MEASUREMENT IN PRIMARY TRIANGULATION

The progress, and hence the cost, of the angular measurements of primary triangulation is the subject of a great deal of study by officials of the Geodetic Survey, since the cost of angular measurements is (in general) a large proportion of the cost of primary triangulation.

Greater changes of procedure and equipment have been made in this part of triangulation operations during the last few years than in any other branch, in order to lessen the cost of this operation. Lighter theodolites have been developed so that equipment could be more expeditiously transported from station to station. Electric signal lamps have superseded the less powerful acetylene lamps for signals on distant stations, on which pointings are made, thus making it possible to work on nights on which haze would have obscured the acetylene lamps; time-switches have been attached to the electric lamps where feasible, to turn them on and off at pre-determined times, thus eliminating the need of quite a number of lightkeepers where these switches can be used, and materially decreasing the cost of the operation; where feasible the triangulation stations are placed more closely together with a consequent shortening of the lines of sight, thus very much increasing the number of nights on which angular measurements can be made.

With all these improvements there are several uncontrollable factors which retard the progress and increase the cost of angular measurements. The topography of the country in many cases limits the shortness of lines, as for example, across wide rivers like the lower St. Lawrence or across Hecate strait between the Queen Charlotte islands and the British Columbia coast, where lines from 60 to 100 miles long are frequently encountered. Similarly the prevalence of fogs in certain parts of the sea coasts and smoke from forest fires, or haziness of the atmosphere in dry periods cannot be prevented, though their effects can sometimes be lessened through the improvements noted above. Also under certain atmospheric conditions the rays of light between triangulation stations may be bent horizontally (an effect called horizontal refraction), a condition which cannot be controlled and which destroys the accuracy of angular measurements. For example, it has been calculated that during one whole season on the lower St. Lawrence river triangulations three times the average number of nights of otherwise good observing weather were required to obtain accurate results, due to the presence of horizontal refraction (conditions in the above area were exceptionally bad in this respect).

To show how the progress of angular measurement varies from year to year and in different localities depending on weather conditions and length of lines, a few outstanding examples are given in the table given below.

Progress of Angular Measurement on Primary Triangulation

	Area No. 1		Area No. 2
	First half of season	Last half of season	Season
Working time (percentage of field season)	33%	9%	59%
Time spent travelling and moving camp (percentage of field season)	27%	10%	21%
Time lost due to fog, haze, bad weather, Sundays, etc., (percentage of field season)	40%	81%	20%
Note—Sundays account for 14% of this total.			
Days per Primary Station	16 days	89 days	5 days
Average length of longest line at stations	25 miles	75 miles	15 miles

In Area No. 1 the first half of the season was spent on short lines in a foggy country, while the latter half was on long lines (about 70 miles) across the sea, where fog was the main obstacle to progress. A comparison of the time lost, and the days per station is very instructive.

In Area No. 2 the lines were short and transportation easy.

It is interesting to know that fog frequently obscures parts of the horizon and leaves other parts clear, so that the engineer may be able to work on only a few of the lights at a time, and the time spent at each station may be large in proportion to the number of nights of work.

The above discussion shows that the problems in connection with the economy of angular measurements on primary triangulation are many and varied. Several lines of action are being pursued:—

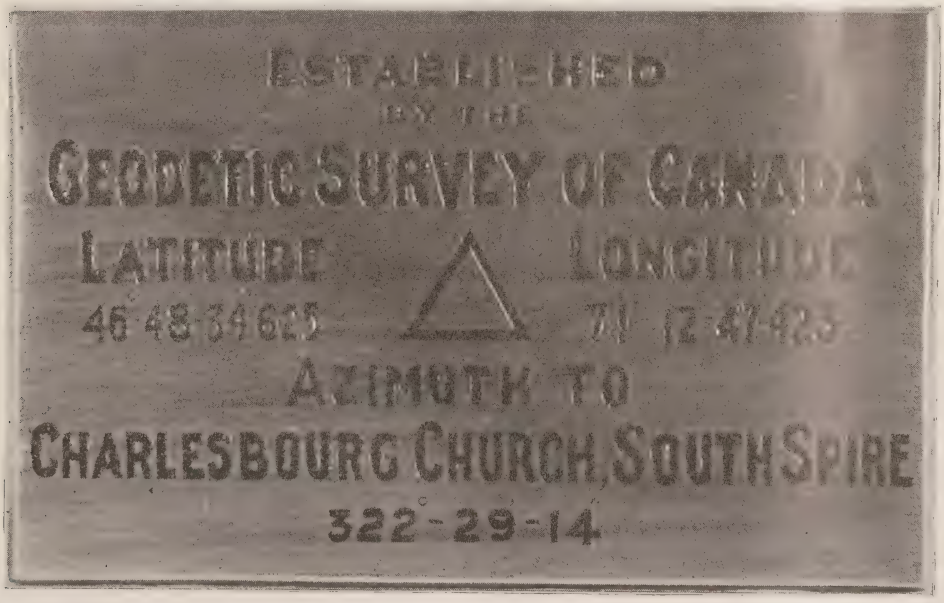
1. Electric lamps are being improved as mentioned above, with gratifying results.

2. Improved angular measurement instruments are being developed, so that the time occupied in obtaining accurate readings is shortened, thus making possible better use of available good weather conditions.

3. Lines are being shortened wherever possible to an average length of about 15 to 20 miles or less.

GEODETIC SURVEY MARKS LESS FREQUENTLY DISTURBED

The operations of the Geodetic Survey in many cases have to be carried on progressively over a comparatively large area by several successive parties, and it is essential to accuracy and economical progress that any structures, instruments, etc., which must often be left unattended be entirely undisturbed. In addition permanent marks, such as triangulation station monuments or marks and precise level bench-marks, must be undisturbed, so that they will be available for use for many years.



Bronze tablet (full size) marking Triangulation Station in stone coping in grounds of Parliament Buildings at Quebec, Que.

The subject of protection in such cases has been studied by Geodetic Survey officials for some years and more gratifying results are now being obtained. Triangulation stations are always located on prominent points, and any activities or apparatus which are out of the ordinary and not easily understood, such as triangulation towers, instrument stands, signal lamps with their clockwork, time-switches, etc., are subjected to the curiosity of meddlesome persons, who do not realize that any movement of these structures or instruments may result in unnecessary delay and expense in the prosecution of the work.

It was early found that prohibitory notices constituted little protection to structures; in fact they probably produced the opposite effect, and finally cards bearing the inscription shown on this page were printed and are placed at each point where structures, instruments, etc., have to be left unguarded. These are printed in English and French, as required, and have produced more

READ FIRST

If you are interested write to the Superintendent of the Geodetic Survey of Canada, Ottawa, for full information, but PLEASE do not touch any instruments or damage this structure in any way.

Parties of engineers are making observations on this and other points in connection with the making of good maps.

If the instruments are moved even the fraction of an inch, or if this structure is damaged, much work may have to be done over again.

You, as a citizen, help pay for this work. Help us avoid unnecessary expense.

PLEASE DO NOT TOUCH

GEODETIC SURVEY OF CANADA

satisfactory results. Less trouble from interference has been met with where these notices have been displayed, while on the other hand in the same area where notices have not been posted, considerable delay has been caused by meddlesome persons. The psychology of the experience is well understood—that prohibitory notices frequently have less effect than appeals to reason and common sense.

The principal of inconspicuousness had previously guided the marking of triangulation stations, but the inconspicuousness of these marks has frequently led to difficulty in finding them, when the engineers are unfamiliar with what to look for. Lately more conspicuous marks, consisting of bronze tablets in concrete monuments, have largely been employed, bearing the inscription, "Geodetic Survey of Canada, Triangulation Station (or Reference Monument, etc.). For information write the Director, Ottawa."

The above inscription and the notices mentioned above have resulted in the receipt of a very large number of inquiries as to the purpose of this work and have enabled this Survey to supplement the efforts of its field engineers in explaining the work to all who wish information.

OPERATIONS OF THE SURVEY

Precise Levelling

(F. B. Reid, Supervisor of Levelling)

Three precise levelling parties were in the field in the summer of 1923—in charge of Messrs. McMillan, Sinclair and Raley the first of these being engaged in New Brunswick and the Eastern Townships of Quebec, the second in northern Ontario and Quebec and the third in Manitoba and northern Ontario. A fourth party in charge of Mr. R. H. Montgomery, was engaged in special work on the coast of Labrador in July and August.

Precise Levelling in New Brunswick and Eastern Townships of Quebec

(D. McMillan)

Mr. McMillan left Ottawa on May 15 for Gagetown, N.B., to continue the precise levels up the St. John river valley from the point where they had been discontinued in the fall of 1922. The Canadian National railway was followed through Fredericton to Woodstock, where a closure was obtained on a previously established precise bench-mark; a connecting link was also run between Fredericton and McGivney, following the valley of the Nashwaak river for the greater part of the way and closing on a bench-mark of the Grand Falls-Moncton line at McGivney.

The New Brunswick work being completed on July 24 the party moved to the Eastern Townships of Quebec and spent the balance of the season, till October 18, in rerunning from Stanstead through Sherbrooke, Foster and Farnham to St. Johns, including the branches from Foster and Farnham to the international boundary. These lines were amongst the very first to be run by this Survey, having been levelled in the year 1907 and it was felt that many of the bench-marks established and at that time intended to be permanent did not possess the requisite degree either of permanence or stability; the subsequent closure of precise level circuits in the vicinity, moreover, made it appear that parts of the work were not up to the usual standard of accuracy. The completion of the rerunning resulted in improving the closures of four out of the five circuits affected and at the same time disclosed the fact that some 28 per cent of the original bench-marks had been destroyed and certain of the remainder had shifted, the unstable ones being for the most part in boulders. The number of bench-marks originally established was 58, of which 42 were found to be still in existence; during the rerunning 74 new ones were established, practically all of which will undoubtedly possess great permanence and stability owing to the care used in selecting the sites in the light of experience gained since 1907. The district covered by these precise level lines may in consequence now be considered to have an ample supply of bench-marks of the highest accuracy and

stability. In regard to the improvement in accuracy it is only fair to say that most of the trouble in the original lines was probably caused by undetermined rod errors in the wooden levelling rods used at that time. In later years more satisfactory methods of standardizing the wooden rods have been developed and during the present season rods carrying the graduations on a strip of invar were used; in these every confidence may be felt.

During the season 141 bench-marks were established by this party which may be classified as follows: standard bench-mark piers, 21; buildings, 28; bridges and culverts, 83; solid rock surfaces, 3; boulders, 3; international boundary monuments, 3.

Precise Levelling in Northern Quebec and in the City of Quebec and Vicinity

(G. E. B. Sinclair)

Mr. Sinclair left Ottawa on May 13 for Lowbush, Ont., a point on the Canadian National railway, 42 miles east of Cochrane. The previous year's levels from the west were continued easterly along the railway until on September 14, Oskelaneo River, Que., had been reached. At this point the regular operations were closed and the party disbanded.

Mr. Sinclair then proceeded to the city of Quebec and spent the next two months in the city and surrounding district establishing 163 additional bench-marks of the bronze tablet type, this work being an extension of that done within the city limits in the fall of 1922. The Quebec levelling was carried out under the usual co-operative arrangement whereby the Geodetic Survey loans the services of the geodetic engineer in charge and the city bears all other expenses.

During the season 122 bench-marks were established on the main line of levels through northern Ontario and Quebec, which may be classified as follows: standard bench-mark piers, 15; buildings, 17; bridges and culverts, 87; solid rock surfaces, 3. Of the 163 bench-marks in the Quebec vicinity levelling 107 were in buildings, 26 in bridges and culverts, 8 in standard bench-mark piers, 3 in historic monuments and 19 in miscellaneous objects. As this work was done in order to give levelling control to the city of Quebec and vicinity the selection of the sites for the bench-marks was left to the City Engineering Department; the installation of the bronze tablets was also taken care of by the city authorities.

Precise Levelling in Vicinity of Winnipeg and in Sioux Lookout-Fort William District

(G. S. Raley)

Mr. Raley left Ottawa on May 8 for Winnipeg and extended a line of precise levels along the Canadian National railway branch from Winnipeg to Victoria Beach, Man. The immediate purpose of this line was to obtain a check, by means of water transfers across lake Winnipeg, on the elevation determined in the winter of 1922-23 for the bench-mark at Fort Alexander, at the mouth of the Winnipeg river. The levels to Fort Alexander, it may be remarked, had been carried over the ice down the course of the river from Kenora and Minaki, as described in last year's report.

On the completion of the Victoria Beach line Mr. Raley moved to Superior Junction, Ont., and ran levels along the Lake Superior branch of the Canadian National railway to its junction with the Port Arthur-Winnipeg main line near Rowan, Ont. This piece of levelling was begun on July 2 and finished

on September 27, its completion being the means of closing a circuit of levels extending through Winnipeg, Superior Junction, Rowan, Fort Frances, Rainy River and Winnipeg. The perimeter of this circuit is 831 miles and the noteworthy closing error of 0.0025 foot was obtained. The constituent lines of this circuit were run by four different engineers of the precise levelling staff, in the years 1913, 1917, 1920, and the present year.

During the season 82 bench-marks were established, which may be classified as follows: standard bench-mark piers, 32, buildings, 8; bridges and culverts, 8; solid rock surfaces, 30; boulders, 4.

Precise Levelling on the Labrador Coast

R. H. Montgomery

In answer to a request from the Department of Justice, Mr. Montgomery left Ottawa on July 5 to join the Canadian Government Steamer *Arctic* at Quebec and proceed to the Labrador coast for the purpose of running precise levels between Hamilton inlet and lake Melville. This work was done in co-operation with the Hydrographic Survey, Department of Marine and Fisheries; automatic tide gauges were established at lake Melville and at the head of Hamilton inlet and were connected by precise levels run along the shore line—the total distance involved being some 18 miles. Nine bench-marks were established, these being of the bronze tablet type, set in rock, the same as previously used in the Winnipeg and English river levelling.

Owing to the very rugged nature of the country a Zeiss level of the pattern adopted by the British Ordnance Survey was used in place of the larger precise level regularly used. On account of the comparatively light weight of the Zeiss instrument it was much more readily handled; in fact, it would have been practically impossible to use an instrument of the size and weight of that commonly used by this Survey, on some parts of the work. In spite of physical difficulties it was found possible to keep the discrepancy between the forward and backward levelling within the limits set for levelling of high precision.

Inspection of Bench-Marks

During the summer of 1923 an inspection was made of the bench-marks between Salisbury and Albert, N.B., St. John, Fredericton and McGivney, N.B., Winnipeg to Victoria Beach, Man., and Winnipeg, Man., to Cochrane, Ont., also the bench-marks established the previous fall in the city of Quebec and vicinity. These lines were inspected in accordance with the customary policy of the Survey of having all bench-marks inspected as soon as practicable after their establishment and before the results of the levelling are issued to the public.

In addition to the above the line from St. John to Moncton, N.B., run in the year 1910, was also inspected in order to note the condition of the bench-marks after the lapse of thirteen years. It was found that 11 out of the 34 bench-marks originally established had disappeared, these being for the most part in stone structures (bridges and culverts) which had been reconstructed since the date of the levelling. Most of the bench-marks still in existence were in good order and appeared to have been undisturbed. In the same connection it is to be noted in the section of this report dealing with Mr. McMillan's work that in rerunning certain lines in the Eastern Townships of Quebec originally run in 1907 it was found that 16 out of the 58 bench-marks originally established had been destroyed.

While it is not to be inferred that the mortality amongst the bench-marks of the whole precise level system is on anything approaching the scale indicated above, as the question of permanency and stability of the bench-marks has

received considerably greater attention in the more recent lines, nevertheless the observations made during the past summer indicate the necessity of periodic inspections of the bench-marks in any particular district every few years; not only is it to be expected that a certain percentage of them will be found to have been destroyed but the original description of others may have become inapplicable on account of the alteration or destruction of reference objects, revision of railway mileages, etc.

Summary of Field Work

The mileage run by each engineer is shown in the following table, also the percentage of relevelling, the number of standard bench-mark piers built and the total number of bench-marks established, including piers:—

Engineer in charge	Mileage levelled	Percentage relevelled	Bench-mark piers built	Total Bench-Marks established
D. McMillan	303	9%	21	141
G. E. B. Sinclair	307	12%	23	285
G. S. Raley	237	16%	32	82
R. H. Montgomery	18	*	0	9
	865	.....	76	517

*On account of the rugged nature of the country and the lack of any properly defined route for the levels, nearly all the work had to be relevelled one or more times.

Of the 303 miles levelled by D. McMillan but 137 miles was new work, the balance being rerunning of old work. This leaves a total of 699 miles of new levelling added to the precise level net during the fiscal year. The following is a summary of the season's levelling:—

Line	On Railway	Off Railway	Total
Gagetown to McGivney, N.B.	66·3	1·2	67·5
Fredericton to Woodstock, N.B.	63·3	0·7	64·0
Beebe Junction, Que., to Newport, Vt.	6·0	0·0	6·0
Lowbush, Ont., to Oskelaneo River, Que.	251·2	0·0	251·2
Quebec City Lines	·0	55·5	55·5
Winnipeg to Victoria Beach, Man.	74·0	0·1	74·1
Superior Junction to Rowan, Ont.	163·0	0·0	163·0
Hamilton Inlet to Lake Melville, Labrador	0·0	17·8	17·8
	623·8	75·3	699·1
Rerunning Old Levelling			
Stanstead to Sherbrooke, Que.	38·4	1·6	40·0
Sherbrooke to St. Johns, Que.	77·1	3·5	80·6
Foster to Abercorn, Que.	22·5	0·5	23·0
Farnham to St. Armand, Que.	21·5	0·2	21·7
	159·5	5·8	165·3

Previous to 1923, 16,322 miles of levelling had been accomplished; the total to date is therefore 17,021 miles.

Five hundred and seventeen bench-marks have been established this year, which brings the total number at the present time to 5,559—not including those of other organizations which have been connected with our levelling.

The mileage of the levelling since the beginning of the work is distributed among the provinces as follows:—

Province	Previous to 1923	1923	Total
Ontario	5,270	197	5,467
British Columbia	2,264	0	2,264
Saskatchewan	2,088	0	2,088
Quebec	1,788	290	2,078
Alberta	1,519	0	1,519
Manitoba	1,153	74	1,227
New Brunswick	964	132	1,096
Nova Scotia	729	0	729
Yukon Territory	458	0	458
Minnesota, U.S.A.	89	0	89
Vermont, U.S.A.	0	6	6
	16,322	699	17,021

It is distributed among the railways as follows:—

Railway	Previous to 1923	1923	Total
Canadian National	7,549	618	8,167
Canadian Pacific	5,890	0	5,890
Timiskaming & Northern Ontario	320	0	320
Great Northern	230	0	230
Algoma Central	219	0	219
Dominion Atlantic	146	0	146
Quebec Central	109	0	109
White Pass and Yukon	91	0	91
Temiscouata	82	0	82
Ottawa and New York	55	0	55
Pere Marquette	55	0	55
Boston and Maine	34	6	40
Maine Central	36	0	36
Napierville Junction	28	0	28
British Columbia Electric	28	0	28
Quebec Ry. Light and Power Co.	25	0	25
Maritime Coal, Railway and Power Company	12	0	12
Pacific Great Eastern	9	0	9
Michigan Central	3	0	3
London and Port Stanley	2	0	2
Highways and cross-country levels	1,399	75	1,474
Total	16,322	699	17,021

Adjustments and Geodetic Research

(W. M. Tobey, Senior Geodetic Engineer)

The work of the adjusting office was mainly a development and improvement of the lines of the previous year. Thus there was a continuation of:—

(*a*) Special or research work.
(*b*) General investigational problems.
(*c*) Analysis of field results.
(*d*) Furnishing adjusted data.
(*e*) Adjustment of triangulation and level nets.
(*f*) Determination of the precisions or probable accuracy of various parts of the triangulation and level nets as advisory for new field work.

Special or Research Work.—This work has been mainly confined to the refinement of geodetic formulae (e.g., geodetic position evaluation, Publication No. 7); to geodetic problems; to the discussion of the accumulated errors of field

work; to the extension of the theory of adjustments to bring about differential adjustments and adjustments of precise traverses, and to the mathematical analysis of certain observations, e.g., say of elastic steel tapes.

The subject of traverse adjustments should be specially mentioned as the method of treatment was unusual. A short description of the methods developed will be found on page 53 of the annual Report of the Director of the Geodetic Survey of Canada for the fiscal year ending March 31, 1923.

General Investigational Problems.—This phase of the work refers particularly to the subject of accumulative error. Remembering that each field man's work is local or regional, it follows that each field man's accuracy is determined by his methods and is of a local or regional character. There is always a "left over" error in each field man's work and this left over error may be of a very peculiar nature.

To join up the work of all the individual field men and to unite all the "left over" errors forms a subject which is of the utmost importance to the accuracy of geodetic work. By this means only can the accumulative error be investigated and by this means only is a real correlation of field work consummated.

Analysis of Field Results.—The usual office analysis of field results was undertaken. The methods employed were described on page 54 of the Annual Report of the Director for the fiscal year ending March 31, 1923.

Furnishing Adjusted Data.—Generally requests for data came from the different federal departments, the provincial departments and private engineering firms. The federal departments supplied with such data were the National Defence, Public Works, Geological Survey Branch, Department of Mines, and the following branches of the Department of the Interior: Topographical Survey, International Boundary Commission and the Natural Resources Intelligence Service. Information was also supplied to a number of the surveying and other organizations of Provincial Governments, engineers of various cities and to many private engineers.

The preparation of adjusted geodetic work for the International Union of Geodesy and Geophysics to be held in Madrid, Spain, during October, 1924, was undertaken along the same lines as the work submitted to the Rome conference of the International Union of Geodesy and Geophysics in 1922. The work for the Madrid report thus covers the years 1922 and 1923 of geodetic activities for Canada. In this work precisions of the results and of different parts, always so necessary for a basis of comparison of the accuracy of the work as a whole, were also collected; these precisions including not only those for different parts of a complex interwoven system of the adjustment, but also including the cases of all the measured bases and of the azimuths and longitudes of the work entering into the Laplace results.

Adjustment of Precise Level Nets.—Mention might well be made of the great value of the differential adjustment which has lately been inaugurated in connection with the adjustments of the level nets. Applied to the level adjustments (where the adjustment was that of conditions) it means that the effect of new data or corrections to previous work can be definitely evaluated. The adjustment will be final when new data does not sensibly affect previous adjustments. All this is done as if the net were adjusted as an entity, and the principle of Least Squares obeyed. Thus,

First Adjustment.—As stated in the Annual Report of the Director for the fiscal year ending March 31, 1923, this adjustment was based on tidal stations at Halifax and Yarmouth, N.S., and at Father Point, Que., points on

the Atlantic coast. This adjustment covers the whole net as far west as Vancouver. The tidal stations at Vancouver and Prince Rupert, B.C., are not included and their effect on the net does not come in.

The Second Differential Adjustment gives additive corrections to the first adjustment. It takes in the tidal stations at Vancouver and Prince Rupert, and hence includes two new circuits; one joining up the tidal station at Vancouver with one on the east coast and the other joining Vancouver with Prince Rupert. The first adjustment defined mean sea-level of the Pacific at Vancouver with a positive elevation of almost exactly two-thirds of a foot. This two-thirds of a foot was distributed by the second differential adjustment and is necessarily spread through the lines joining Vancouver and the east coast. Its effect is shown on other lines of the net, the greatest effect per mile being close to the direct line and dwindling off as the net spreads to each side.

The Third Differential Adjustment gives additive corrections to the second adjustment and was made necessary by the dividing of a western circuit. This circuit—Edmonton, Tofield, Alix, Lacombe—had originally a closure of 0·7 of a foot, which was considered too large. In order to locate the error the circuit was cut in two by a line running from Camrose to Wetaskiwin. At the same time it was found necessary to relevel the line from Edmonton to Lacombe, and a considerable error was found in the original levels. This change led to large additive corrections over the second adjustment, reaching from Kamloops to Saskatoon and south to Calgary. The largest corrections, outside of the above mentioned, were on the long lines from Port Arthur to Winnipeg, and none of these were greater than 0·01 of a foot.

The Fourth Differential Adjustment—giving additive corrections to the third adjustment, brought in the levelling of the season 1922, viz., the division of the western circuits: (1) Rosetown, Nightingale, Irricana, Alix, by a line from Alaska to Compeer, (2) Rosetown, Alix, Tofield, Saskatoon, by a line from Kerrobert to Unity, (3) the completion of the northern Ontario circuit—Cochrane, North Bay, Sprague, Winnipeg; and (4) the formation of a small western circuit by a new line from Matsqui to Hope, B.C. The chief effects of this adjustment are seen in the immediate locality surrounding the circuits which were broken up, with smaller corrections on the main east-and-west line from Kamloops to Father Point.

The Fifth Differential Adjustment gives additive corrections to the fourth adjustment, as it takes in the levelling of 1923—the division of the circuit Moncton, McAdam, Grand Falls, by levelling lines from St. John to Fredericton to McGivney and from Fredericton to Woodstock in New Brunswick, and the division of the large northern Ontario circuit by a line from Sioux Lookout to Rowan, near Port Arthur. The results of this fifth adjustment are not far reaching. They are confined practically to the circuits which were divided and to a few lines in their immediate neighbourhood.

Determination of the Precisions or Probable Accuracy of Various Parts of the Triangulation and Level Nets as Advisory for New Field Work.—This is a very important function of the triangulation operations. It was described on pages 55 and 57 of the Annual Report of the Director for the fiscal year ending March 31, 1923.

City Mapping

(Douglas H. Nelles, Supervisor of Topography)

The Survey of London, Ont.—The operations were confined to mapping with the plane-table the contours on seven sheets comprising 894 acres, the drafting of which had been completed, and in locating errors in drafting found by office and field inspection. Through the courtesy of the Air Board, the

office inspection was carried on by means of an Eastman projection printer, by means of which the aerial photos were projected upon the map and made to fit approximately. In this way the position of all features could be checked and any missing data noted. The field inspection consisted of taking a full scale photo of the original sheet and checking the detail upon the ground. Missing data found by these methods was, during the course of the field work, surveyed for three sheets.

Investigation re *Drawing Paper.*—In the fall of 1923 it was found that some of the detail on one of the original map-sheets appeared to be in error about two or three feet. At first the error was laid to the shrinkage of the specially prepared zinc mounted bristol board used for the original drawing; but upon fuller investigation it was found that the boxwood-celluloid scale, used for making measurements in plotting, was in error to the extent of one in one thousand (1/1,000), and that the zinc mounted bristol board of the original drawing had remained unaltered during the atmospheric changes that had caused the boxwood-celluloid scale to change its length. This is interesting information, as drawing paper which does not change sufficiently with changing atmospheric conditions to seriously affect the accuracy of the work put upon it, has always been difficult to obtain. In drafting offices where the scale of the map to be reproduced is small and the changes in scale do not make so much difference as they do in a city map, it has been observed that ordinary drawing paper shrinks more in a direction across the grain than with the grain. It is the practice to mount two pieces of the same kind of paper back to back with the directions of the grain in the two sheets at right angles. This causes the combination to shrink equally in every direction and the scale can be corrected by photography.

Gatineau Valley Survey.—The field work of the northern part of the area covered by this survey, namely Thirty One Mile Lake watershed, was completed by the stereophotogrammetric method of survey in 1920 and the results plotted in 1921. Upon giving the original map-sheets of this area a final check inspection, it was decided that it had not been possible to locate five creeks in the northern area with sufficient accuracy by this method and that they should be surveyed by plane-table. Accordingly a small party was sent up to do this work in October, 1923. In four working days they surveyed through the thick bush, eight miles of traverse, which gave the necessary information to have the map completed. The original sheets of the whole 200 square miles have been checked and are ready for publication.

Aerial Photographic Research.—This work has been carried on during the year as time was available. Much valuable data has been collected and formulæ derived for calculating instrumental constants of a proposed machine for plotting maps for aerial photographs. A description of the general design was submitted to the Air Survey Committee of the British War Office, which has reported that the theory is correct and that a practical instrument can be constructed embodying this design. The committee recommended that an experimental instrument should be proceeded with.

Triangulation Operations on the Pacific Coast

(G. H. McCallum)

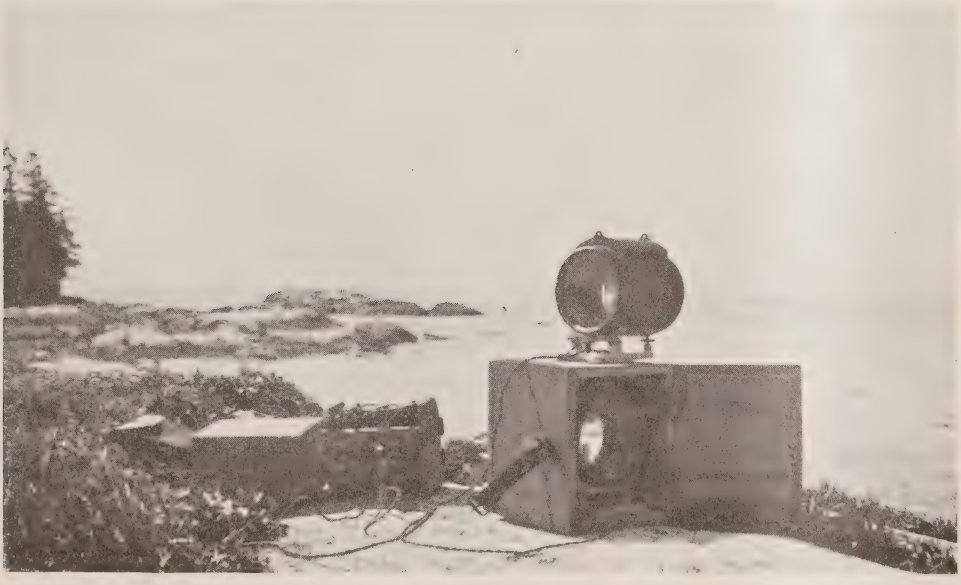
The programme of primary triangulation on the Pacific coast in 1923 consisted of the reconnaissance of the section of the northern British Columbia coast between Princess Royal and Porcher islands, measuring the primary directions, including those across Hecate strait to the Queen Charlotte islands,

and establishing the positions of secondary stations along the shore. The main objective was to complete the connection to the Alaska boundary triangulation near Prince Rupert. This connection was successfully made.

The *Metra* left Vancouver on May 16 with some of the party on board and met the remainder at Swanson Bay five days later. They were taken down to Swindle station, where there is a good beach and camping place. Here the camp equipment was overhauled and sorted out, the various parties were organized, and from here they were distributed to the different stations. As in previous years, the party was divided into two direction measurement parties of four men each—an observer, recorder, cook and lightkeeper; five lightkeepers' parties of two men each, one a trained lightkeeper and signaller and one an assistant; a station preparation party of four, one man in charge and three axemen; and the party of three on the *Metra,* making twenty-five men all told.

In the reconnaissance, three new stations—Bonila, Pitt and Hawkesbury—were located on islands of the same names, respectively. Bonila station is not very high, about seven hundred and fifty feet, and some difficulty was experienced in getting a point on Pitt island from which the line of sight would pass to it over Banks island. The situation chosen on Pitt island is near the middle of the island, but is easily reached by following a narrow unsurveyed inlet which runs into the foot of the mountain. There is foul ground all around Bonila island, with no shelter, and it should always be approached with caution. The line from Hawkesbury to Egeria was very close to intervening ridges and was in doubt until the lights were tried on it and it was found to be open.

Attempts to observe the lines across Hecate strait to Queen Charlotte islands did not meet with much success. The greater part of the month of July was spent on such attempts, but owing to fog and haze the lights were never seen. However, the lines are open and it is proposed to try them again in 1924 at a time when more favourable conditions for observing prevail. In all, eleven primary stations were occupied and completed, nine secondary sta-



A Triangulation Station on the shore along the British Columbia Coast. Two lamps are showing light to Main Trangulation Stations on nearby mountains.

tions were established along the shore and the positions of eight lighthouses were determined. Some of the secondary stations were located at the special request of the Surveyor General of British Columbia to provide a control for local shore traverses.

The Ford lights and converted acetylene lights were used and gave satisfaction. It is necessary to have the latter well focused and well pointed. When they are in focus they throw an almost parallel beam of light that has to be pointed directly at the station to be visible. With care this can be done, particularly in British Columbia where the stations are nearly always on the summits of well defined peaks. When well pointed they give a splendid light to work on. Time clocks were used on some of the lights for the first time in 1923 and are a great saving on easily accessible stations, both primary and secondary.

The *Metra* gave good service as usual. She ran over six thousand miles, which is more than she had run in any previous season. In the first twenty-seven days of September she ran seventeen hundred and twenty-one knots, or nearly two thousand miles. There were only twelve days, including Sundays, during the whole season on which she did not run and on five of these the reason was bad weather.

An ingenious method of illuminating the horizontal axis of the theodolite was used in 1923. It was originated by C. H. Ney, working with a Kern twelve-inch theodolite. The light was electric, the bulb and bracket being part of the regular equipment of the instrument, and the current was supplied by a two-cell flashlight battery wired in series and attached to one of the standards of the instrument; in the circuit and attached to the battery was a small rheostat for varying the intensity of the light. The moving arm of the rheostat was loosely adjusted so that it could be moved by a slight touch not sufficient to disturb the instrument. This arrangement gives an electric lighting equipment complete on the alidade and does away with the long lead from batteries on the ground, with the danger of entanglement when the instrument is turned in azimuth.

On the whole, the weather throughout the season was favourable for observations. During the early part of the summer there was the usual amount of rain and fog with clear weather intervening. In the latter part of August and up to the end of the first week in September there were continual heavy rains with clouds on the mountains and no observing was possible for nearly three weeks. Then for about two weeks there was the clearest weather of the whole season. This was remarkable as there is usually a good deal of rain in this district at that time of the year. The weather broke about the time of the equinox and the party left Prince Rupert on September 23, heading south in a heavy rain with a stiff southeaster blowing.

Alberta-British Columbia Boundary Triangulation

(H. F. J. Lambart)

The determination of control points for the topographical sheets for the Alberta-British Columbia Boundary Commissioners by secondary triangulation, which was commenced in 1922 at the Yellowhead pass, was extended northward along the continental divide to its intersection with the 120th meridian in 1923. (The continental divide south of the above intersection, and the 120th meridian north, form the interprovincial boundary.)

The organization at Jasper of the two observing and one reconnaissance party engaged on this work was completed and they left for their fields of operation on June 14.

Mount Ida on the Jarvis pass, 125 miles by Air Line Northwest of the Yellowhead pass. View taken from Geodetic Station Sentinel.

Cairn at Geodetic Station Haig, near Sheep Creek pass, North of Jasper on the British Columbia-Alberta Boundary.

Headwaters of Muddy river, just east of the British Columbia-Alberta Boundary, north of Jasper. Geodetic Station Gilbert in the center.

Packing Instruments and Outfit up to a Triangulation Station near Swanson Bay on the British Columbia Coast.

One observing party commenced work at the Yellowhead pass, while the other two, whose work lay far north of the railway, reached their territory by way of the Robson pass.

Up to 1923 no connection had been made between the boundary work being carried southward by R. W. Cautley (Alberta Boundary Commissioner) along the 120th meridian, and the work progressing northward along the watershed of the Rocky mountains. In 1923 however, "Torrens Cairn," one of Mr. Cautley's stations (the position of which is known with reference to the projected meridian), was located with reference to our triangulation, and the intersection of the meridian and the continental divide was thereby found to be near what is known locally as the Sheep Creek pass, 18 to 20 miles south of the Jarvis pass. This places the above intersection approximately 85 miles north of the Yellowhead pass.

The triangulation net has been laid out between two base lines, one at the Yellowhead pass and the other in the broad valley of the Porcupine river at the eastern end of the Jarvis pass. The measurement of the Yellowhead base line was completed in February, 1923, on the ice of Lucerne lake and the ends of the base permanently marked by concrete piers. The reconnaissance work, including the location of the Jarvis Pass base, was completed during the year, leaving for the field season of 1924 most of the observing of the horizontal and vertical angles, the measurement of the Jarvis Pass base and the Laplace points which are to be established, one at each of the bases.

Triangulation along the Forty-Ninth Parallel

(W. M. Dennis)

The section from the 109th meridian to lake of the Woods forms the Canadian share of a continuous arc of primary triangulation from the Pacific ocean to the lake of the Woods which is being executed along the 49th parallel under a co-operative arrangement between the Geodetic Survey of Canada and the United States Coast and Geodetic Survey. This arc, thus situated, will satisfactorily fill the requirements of both countries for the adjacent territory, and will relieve each country of a large portion of the expense necessary to satisfy those requirements independently.

Raising the first side of the tripod by horse power on the Primary Triangulation along the 49th Parallel.

Taking readings from the top of a Reconnaissance Tower 80 feet high along the 49th Parallel.

Raising the third leg of the tripod of a 60-ft. tower along the 49th Parallel.

Reconnaissance.—After completing a revision of the reconnaissance through the Turtle mountains, reconnaissance for primary triangulation was successfully carried from the line "Darlingford-Maida" on the 49th arc to the line "Canada-States" on the United States coast and Geodetic triangulation along the 98th meridian, a total distance of about 125 miles. From this line in the vicinity of Emerson to the base line at Warroad by way of the Canadian National railway, a distance of about 90 miles, stations were chosen and the height of towers ascertained for carrying the main azimuth line of a precise traverse. This type of control will be used in this section in preference to triangulation because of the swampy nature of the country and the consequent difficulties in transportation. This work completed the reconnaissance for selection of stations along the Canadian section of this work.

A week was then occupied in looking into the possibilities and probable cost of a chain of primary triangulation down the Red River valley to Winnipeg. This, it was found, would be expensive and the party was instructed to complete the reconnaissance for a chain of primary triangulation from the 49th parallel, ninety miles north to Camp Hughes, in response to a request from the Department of National Defence. From this net triangulation can be supplied to the city of Brandon, and it was laid out to permit of extension to the north to join any future arc along the northern lines of railways. The party was disbanded on September 16.

Pier Building.—The sole duty of this party was to place the concrete piers, described in the report for 1922, to mark the triangulation stations. In this part of the work a great amount of manual labour is involved, as the stations are on the tops of hills and the material to be removed generally consists of hardpan with a large proportion of rock. In each case approximately six tons of material must be excavated and a ton of concrete placed. The pier is built in two sections and the lower section must be allowed to set at least fourteen hours before the top is placed, which makes it necessary to camp in a central location and work the stations in groups. Notwithstanding delays due to this system, 67 piers were set in a period of 88 days available for this work.

Direction Measurement.—The results obtained from the work of this party were very satisfactory. A large amount of work was completed, although weather conditions until the end of July were poor. The effect of these conditions was felt more in connection with transportation than on the actual observation. Almost all the storms were severe but of short duration, so that in an hour or so conditions might be quite satisfactory for direction measurement, while it might be almost impossible to use mechanical transport for two days. Thus, after a severe storm the work might be completed and yet the party be prevented from moving to the next location.

Two stations, completed the previous year, were reoccupied; thirty-three new stations of the primary triangulation were occupied; seven of these were reoccupied and in five other cases angles were reobserved before the outfit was moved.

From the 109th meridian east to the 105th the country is very sparsely settled and few structures of a permanent nature could be cut in for secondary control. Eastward from the 105th meridian, however, more marks of this class are available and their positions have been determined where possible.

With very few exceptions, the position of one land survey post in the vicinity of each primary triangulation station was established. In this way both the United States and the Canadian land surveys have been supplied with definite control at intervals of approximately 15 miles throughout the length of this work—some 265 miles. To date it has been possible to locate stations of the International Boundary triangulation at the points designated by the commissioners.

The boundary between North Dakota and Montana was not directly tied in to our work, as it meets the 49th parallel in a depression which made the required connection difficult. Indirect control was obtained by tying in a station of the International Boundary triangulation just west of the North Dakota-Montana state line. This station is connected with the state line by the International Boundary triangulation.

Summary of Results:—

Reconnaissance—134 miles primary triangulation; 2,282 square miles covered; 76 miles of precise traverse; 22 primary and 11 precise traverse stations chosen.

Pier Building—348 miles completed; 5,050 square miles of triangulation supplied with piers; 67 concrete piers placed.

Direction Measurement—186 miles primary triangulation completed; 3,422 square miles covered; 35 stations of main scheme occupied for horizontal angles; 33 stations of main scheme occupied for vertical angles; 8 stations of the International Boundary triangulation established with respect to position, and geodetic azimuth of lines from two of them determined; 29 land survey posts tied in; 12 secondary points, such as schools, churches, etc., located by three intersections; 7 others by two intersections with single directions to 13 similar points.

University of Toronto Survey Camp Connected to Primary Triangulation

(Professor L. B. Stewart)

This connection was effected by a secondary triangulation net between the villages of Minden and Coboconk, Ontario. On the establishment of the University of Toronto Survey Camp at the head of Gull lake, near the village of Minden, the advantage to be derived from a survey connecting points in the neighbourhood of the camp with a primary station of the Geodetic Survey was at once recognized, so that the staff in surveying resolved to carry out such a survey at the earliest opportunity. In the fall of 1921 the writer suggested that the best plan would be to lay out a chain of triangles connecting the primary stations Anson and Somerville, the former of which is about five miles west of the survey camp; the scheme could then include one or more points near the camp.

Professor L. B. Stewart took charge of this work and the reconnaissance was begun early in June, 1923. The line between Somerville and Anson was closed, owing to the growth of timber on the high land in the vicinity of the village of Dongola since the line was observed in 1910; it was, therefore, decided to dispense with the direct use of that line. Five secondary stations were then established near the villages of Coboconk and Dongola, in the northeasterly corner of the township of Laxton, to the south of Miner's bay, and near the head of Gull lake, the last point being within a quarter of a mile of the camp. Towers were required at the stations of Laxton and Dongola, their heights being 78 and 40 feet respectively.

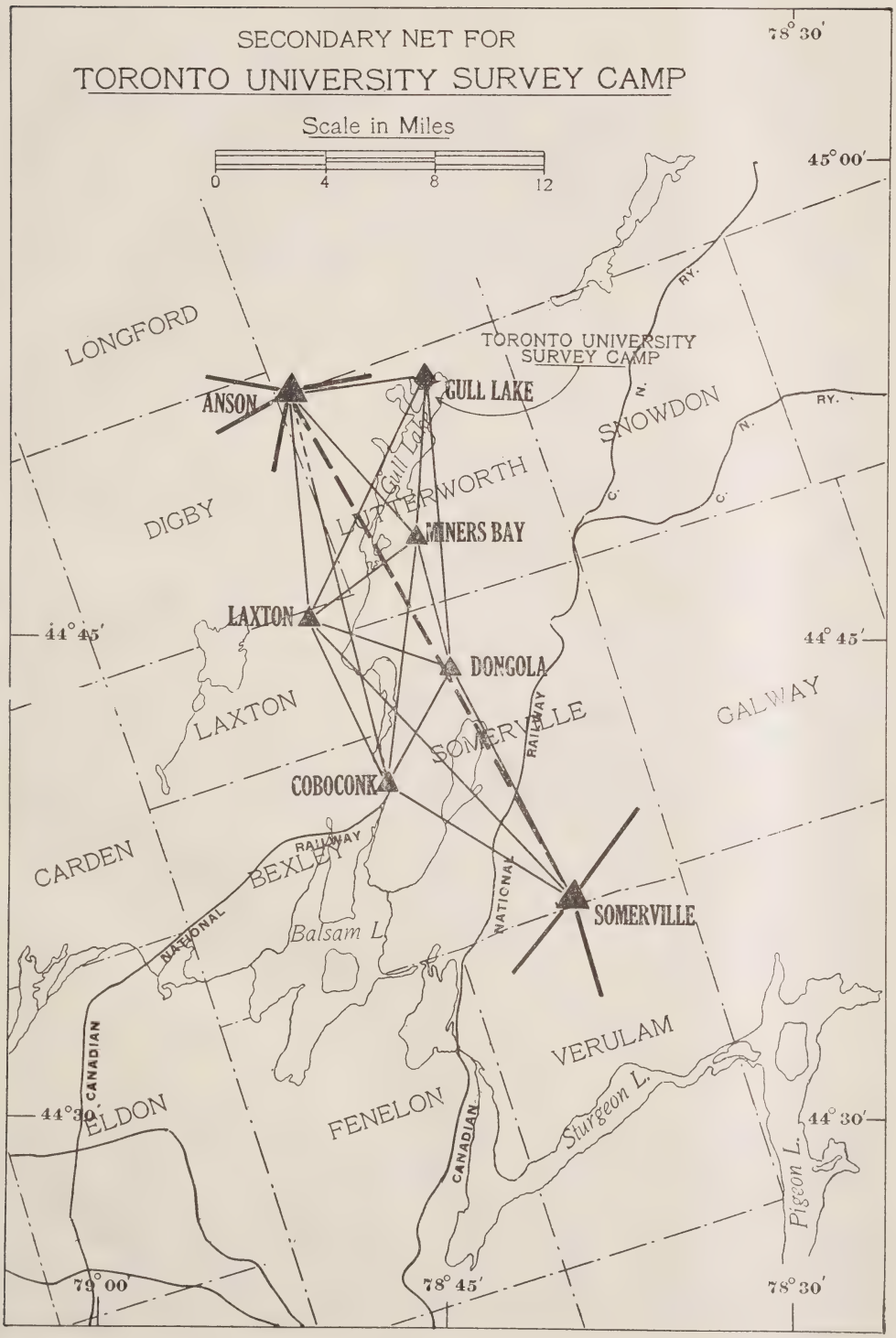
On the completion of the towers the angles were observed by the repetition method, using a 7-inch theodolite reading by verniers to 10″ ~~inches~~. This instrument, however, did not prove entirely satisfactory, as it was found on testing the observed values of the angles by means of the triangle errors, using the fourteen triangles contained in the figure, that the observed values of the angles were systematically too small; the triangle errors were, with one exception, all positive, their mean value being plus 6″25. The geodetic positions of the stations were then computed setting out with the position for Anson given by the primary triagulation, and following two independent routes, checking on the position given for Somerville.

The following insert should be read after the next to last sentence on page 30:—

An examination of the notes seemed to place the source of the trouble in the repetition of the explements of the angles, as, on computing a second set of values, excluding the observations of the explements, the mean value of the triangle error, disregarding algebraic signs, was thus reduced to 2.″7, and, taking account of algebraic signs, to minus 0.″63. The second set of values for the angles was, therefore, adopted and this procedure is further justified by the result of the final adjustment of the angles, which gave 1.″18 as the mean value of the corrections to the angles, without regard to algebraic signs, and minus 0.″06 as the mean value on taking account of algebraic signs, the maximum correction being minus 2.″64.

The adjustment having been made, it was then necessary to solve the triangles, finding the lengths of the lines in terms of the length of that between Anson and Somerville given by the primary triangulation. This was effected by assuming a length for the line from Dongola to Somerville, solving the triangles, and thence finding the corresponding length for the line from Anson to Somerville.

By subtracting the logarithm of this value from that given by the primary triangulation the logarithm of the ratio of the corrected length of any line to that given by the preliminary solution of the triangles was obtained. The lengths of the lines were corrected accordingly.


SECONDARY NET FOR
TORONTO UNIVERSITY SURVEY CAMP
Scale in Miles
0
4
8
12
78° 30′
45° 00′
LONGFORD
TORONTO UNIVERSITY SURVEY CAMP
ANSON
GULL LAKE
SNOWDON
DIGBY
LUPTERWORTH
MINERS BAY
LAXTON
44° 45′
DONGOLA
LAXTON
SOMERVILLE
GALWAY
COBOCONK
CARDEN
BEXLEY
Balsam L.
SOMERVILLE
VERULAM
Sturgeon L.
ELDON
FENELON
44° 30′
Pigeon L.
79° 00′
78° 45′
78° 30′
CANADIAN NATIONAL RAILWAY

Primary Triangulation on the Upper Ottawa

(A. M. Grant)

The first work was the completion of the secondary triangulation in the city of Quebec, and surrounding district. This occupied the period from May 25 to June 19, and included the addition of several new stations and the connection of points previously established with street lines and permanent monuments. One of the new stations established was on the top of the north cantilever arm of the Quebec bridge. This station, although on such a high structure, was very suitable as an instrument station. The passing of trains over the bridge did not interfere with observations as much as the passage of street cars interferes with the average station on a sidewalk twenty feet from the car track.

On June 29 work was started on the main operation of the season, the extension of the primary triangulation up the valley of the Ottawa river, commencing at the stations Alleyn and Masham on the Gatineau scheme, crossing the Ottawa river in the vicinity of Arnprior and Renfrew and then continuing up the valley of the Ottawa with stations on both sides of the river. The operations comprised the preparation of ground stations for observing, building of towers where necessary, and angular measurements.

The preparation of the ground stations was first in charge of W. N. McGrath, with one assistant, and later of H. M. Barton. This party used a light delivery car for transport, and in this section of the country it was very efficient and convenient. This party disbanded on August 25.

The observing was carried on by A. M. Grant with only one assistant, no lightkeepers. Automatic time switches were used to operate the electric lamps, which were distributed to the different stations, moved from one station to another, or the pointing changed from one line to another, by the engineer and his assistant working separately (each using a light delivery truck for transportation and each taking a different round of stations and meeting at the station which was being occupied). This system worked satisfactorily, for although the total progress for the season was probably smaller than would have been the case had lightkeepers been used, the cost per station for observing was quite low considering the roughness of the country and the average length of lines.

On the stations overlooking the Ottawa river many church spires, water tanks and other secondary points were cut in from the primary stations, giving good control points over the whole territory.

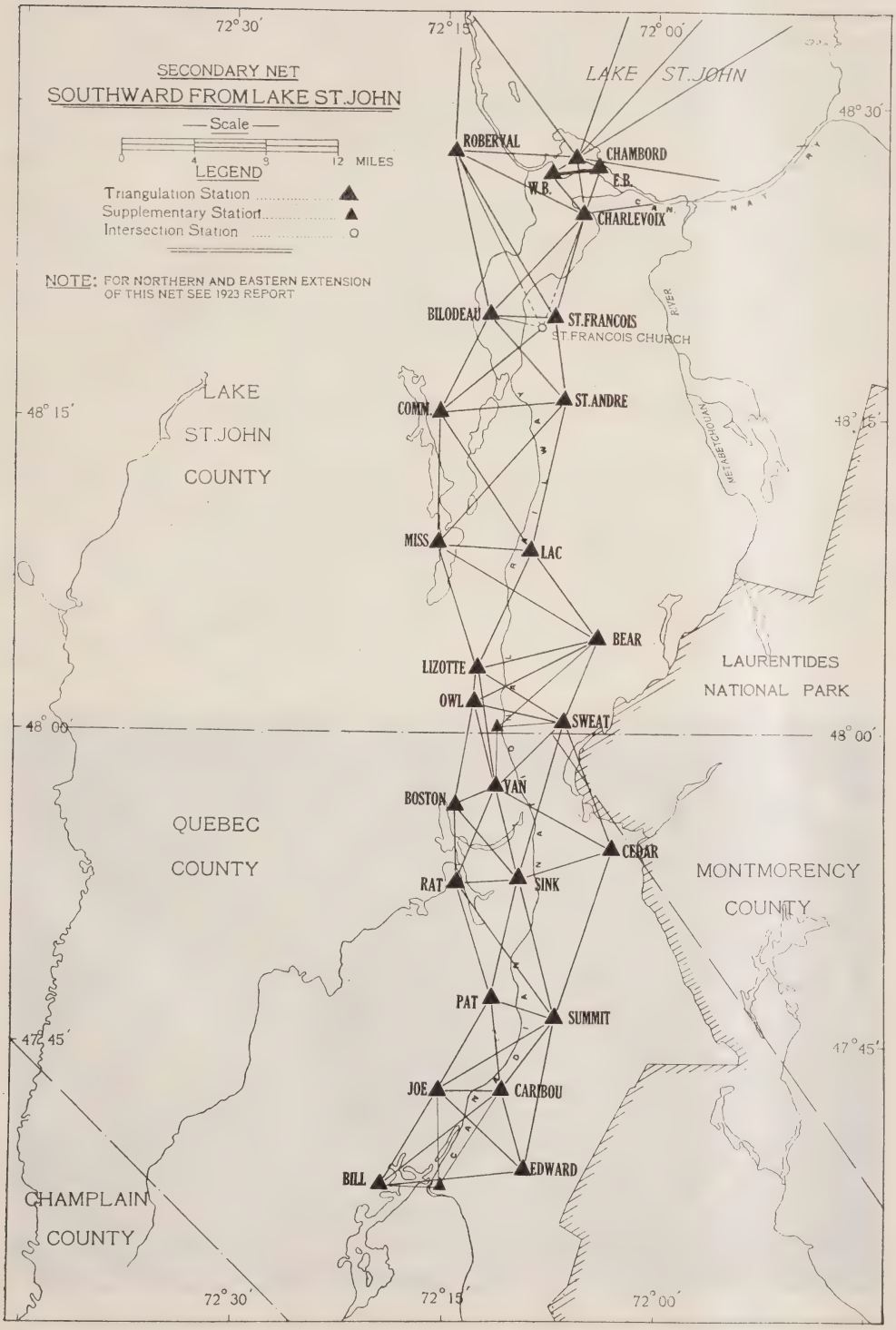
Observing was discontinued on November 9, on account of the bad condition of the roads—rather than that of the weather.

Secondary Triangulation—Saguenay District

(John W. Menzies)

The party assembled at Roberval, lake St. John, on May 22. The first work undertaken was the location and measurement of a base line; this was completed by the middle of June.

On completion of this work the secondary triangulation was carried on southerly from the line Roberval-Charlevoix, keeping astride the Quebec and Lake St. John railway. Both reconnaissance and observing were seriously interfered with by the prevalent forest fires: this condition continued until about the end of July. In September the work was again seriously delayed by rainy weather.


SECONDARY NET
SOUTHWARD FROM LAKE ST.JOHN
— Scale —
0 4 8 12 MILES
LEGEND
Triangulation Station
Supplementary Station
Intersection Station
NOTE: FOR NORTHERN AND EASTERN EXTENSION OF THIS NET SEE 1923 REPORT
72° 30′
72° 15′
72° 00′
LAKE ST.JOHN
48° 30′
ROBERVAL
CHAMBORD
W.B.
E.B.
CHARLEVOIX
BILODEAU
ST.FRANCOIS
ST FRANCOIS CHURCH
RIVER
LAKE ST.JOHN COUNTY
48° 15′
COMM.
ST.ANDRE
MISS
LAC
BEAR
LIZOTTE
OWL
SWEAT
LAURENTIDES NATIONAL PARK
48° 00′
BOSTON
VAN
QUEBEC COUNTY
CEDAR
MONTMORENCY COUNTY
RAT
SINK
PAT
SUMMIT
47° 45′
JOE
CARIBOU
BILL
EDWARD
CHAMPLAIN COUNTY
72° 30′
72° 15′
72° 00′

The absence of roads and trails south of Bouchette railway station made the work difficult. Numerous lakes also added to the difficulty of access to the required points. Pointings were made on cotton signals, composed of two targets made of white cotton, from twenty-four to thirty inches square, mounted at right angles to each other on a pole, to the top of which a black and white streamer was tacked. Owing to the wooded nature of the country it was very difficult at times to see the signal, and targets could only be observed on, when the sun was shining from one particular direction. The spruce sky line added to these difficulties.

Connections were made with the astronomical piers at Roberval and Lake Edward; also with land survey posts on the 48th parallel of latitude at its intersection with the railway.

During the season thirty stations were located and observed, with an average length of line of about seven miles. Towers were built at fifteen stations, ranging in height from twelve to forty-five feet.

The party was disbanded October 27.

Triangulation of the Lower St. Lawrence and Gulf Area

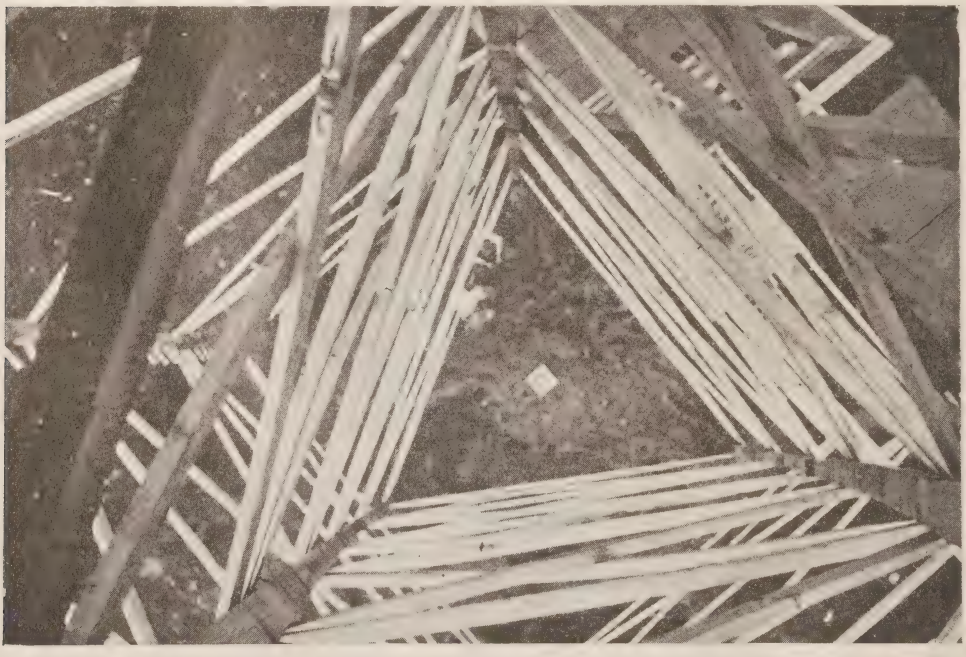
(W. C. Murdie)

The triangulation of the Lower St. Lawrence and Gulf area was carried on during the field season of 1923 under the following organization:—

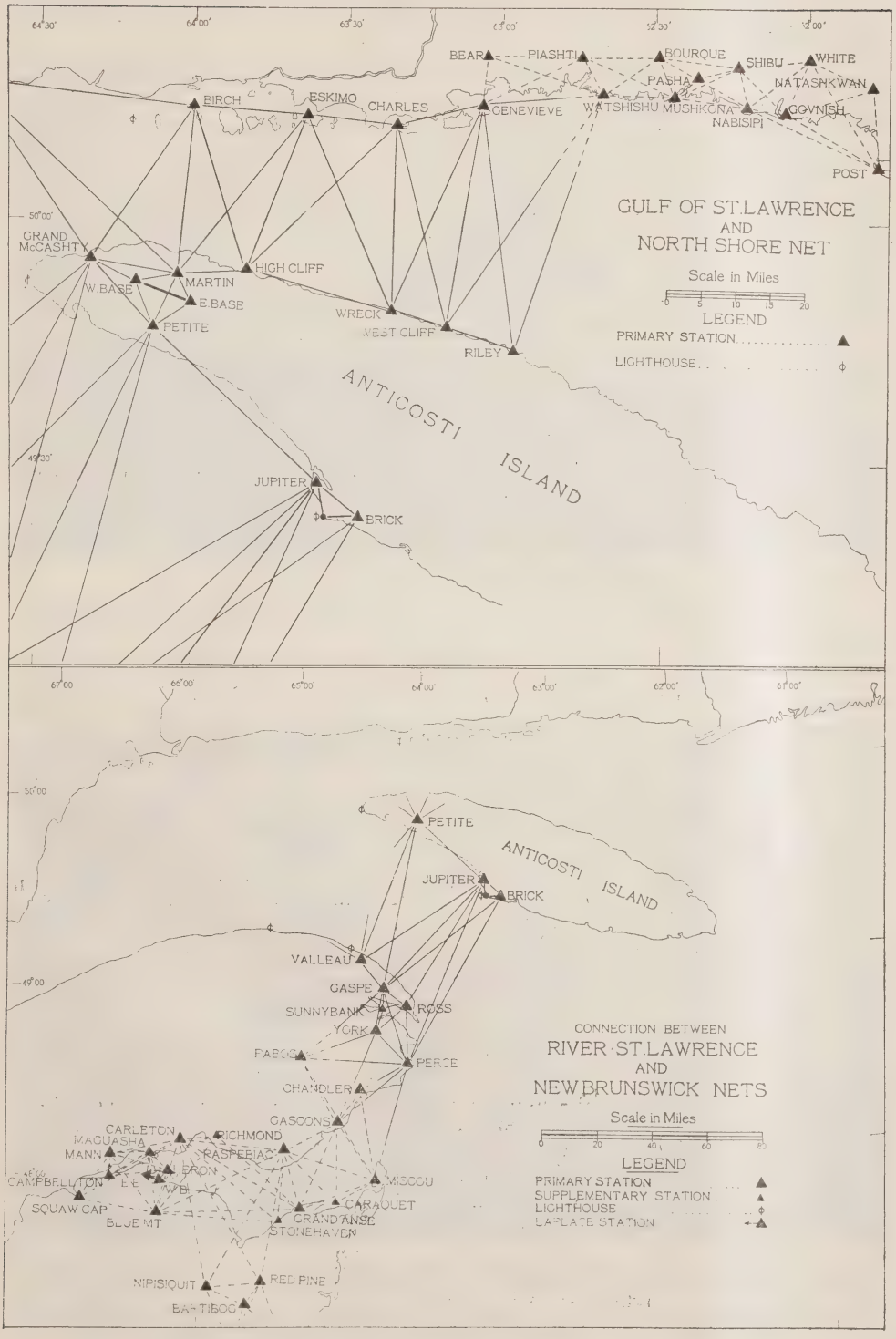
1. Engineer in charge of operations, with headquarters on C.G.S. *Gulnare*.

2. Direction Measuring.—Two direction measuring parties under J. H. Kihl and H. G. Rose, each comprising a recorder, helper and cook. Up to June 13 the latter party was under J. M. Riddell, who on that date took charge of the reconnaissance on the north shore of the gulf of St. Lawrence.

3. Tower Building.—Under C. K. McElroy with seven tower builders and a cook.



Looking vertically downward through a 70-foot Triangulation Tower, showing the concrete monument which Permanently marks the Triangulation Station.


64°30'
64°00'
63°30'
63°00'
62°30'
62°00'
BEAR
PIASHTI
BOURQUE
SHIBU
WHITE
PASHA
NATASNKWAN
BIRCH
ESKIMO
CHARLES
GENEVIEVE
WATSHISHU
MUSHKONA
GOVNISH
NABISIPI
POST
50°00'
GRAND McCASHTY
HIGH CLIFF
W.BASE
MARTIN
E.BASE
PETITE
WRECK
WEST CLIFF
RILEY
GULF OF ST.LAWRENCE
AND
NORTH SHORE NET
Scale in Miles
0 5 10 15 20
LEGEND
PRIMARY STATION
LIGHTHOUSE
ANTICOSTI ISLAND
49°30'
JUPITER
BRICK
67°00
66°00'
65°00'
64°00'
63°00'
62°00'
61°00'
50°00
PETITE
ANTICOSTI ISLAND
JUPITER
BRICK
49°00
VALLEAU
GASPE
SUNNYBANK
ROSS
YORK
PERCE
CHANDLER
GASCONS
CARLETON
RICHMOND
MAGUASHA
MANN
RASPERIAC
CAMPBELLTON
HERON
WBL
MISCOU
SQUAW CAP
BLUE MT
CARAQUET
GRAND ANSE
STONEHAVEN
NIPISIQUIT
RED PINE
BARTIBOG
CONNECTION BETWEEN
RIVER ST.LAWRENCE
AND
NEW BRUNSWICK NETS
Scale in Miles
0 20 40 60 80
LEGEND
PRIMARY STATION
SUPPLEMENTARY STATION
LIGHTHOUSE
LAPLATE STATION

4. Seven lightkeeping parties, each comprising a lightkeeper and helper.

5. Transportation.—C.G.S. *Gulnare,* with a crew of seven officers and eighteen other ranks.

The *Gulnare* reached Rimouski wharf on the morning of Saturday, May 19. On Monday night, May 21, the tower building party was taken on board and transferred to the Saguenay area, and on May 28 the direction measuring and lightkeeping parties were transferred.

From about the end of May until nearly the end of June, little or no rain fell, and as a result the woods dried up very quickly and forest fires broke out, which not only did a great deal of damage to the country, but developed such volumes of smoke that it was almost impossible to see even short distances. Observing was held up almost entirely until heavy rains near the end of June cleared the atmosphere. Then every advantage was taken of clear weather and the ten primary stations on the Saguenay were completed.

By July 13 the entire party had been transferred to the channel between Anticosti island and the Gaspé peninsula, with headquarters at Gaspé, and work was again in progress. Generally speaking, observing conditions were good, but some delay was caused on the longer lines which were close to the water. The heavy mist that lies over the surface of the sea at times made observing impossible. It is also suspected that night mists formed near the mouth of the Jupiter river on Anticosti island and cut off the view from stations at the eastern extremity of Gaspé peninsula. However, by August 16 nine stations, eight of which were primary and one supplementary, had been occupied and the work in the above-mentioned area was completed.

Thence the party was transferred to the channel between the north shore and Anticosti island, and work was commenced near the west end of the island. Work in the north channel was carried on until early in October, when owing to weather conditions operations were discontinued. On October 5 the direction measuring and lightkeeping parties were returned to the Gaspé coast, after having occupied and completed the work at eleven primary geodetic stations.

Two stations on the Gaspé peninsula were occupied and completed and on October 18 the parties were disbanded.

As a result of the season's operations twenty-nine primary stations and one supplementary station were occupied and completed. All lighthouses and churches within range of the Gaspé peninsula and north channel stations were observed on, together with several Hydrographic Survey signals. Eleven towers were erected and twenty concrete monuments were built. Sufficient lighthouses and churches have been tied in in the Gaspé bay area and on the eastern coast of Gaspé peninsula to serve as good control for any future surveys. It may be noted further that the completed scheme was extended during the 1923 season to the extent of six thousand square miles.

Throughout the season every effort was made to co-operate with the officer in charge of Hydrographic Survey operations on the Lower St. Lawrence River and Gulf area. Two hydrographic stations were occupied and observations were made, which were of use to both the Hydrographic and Geodetic Surveys.

The C.G.S. *Gulnare* was the only means of transportation along the undeveloped and sparsely settled coasts where work was being carried on, and as it is a very suitable boat for the work progress was greatly expedited. Parties were quickly moved and supplies and equipment were always available whenever and wherever required. The system of combined communication by wireless, land line telegraph and signalling by qualified signallers equipped with searchlights, proved as in the past, to be most advantageous in always keeping the engineer in charge well informed of the progress of the work of each party and of any unforeseen interruptions with a minimum delay.

Geodetic Station and Hydrographic Signal on Percé mountain, south of Gaspé, Quebec.

Instrument at Geodetic Station on Gaspé peninsula. This instrument weighs about 35 pounds and is the lightest at present used for Angular Measurements on Primary Triangulation.

During the season every effort was made to co-operate with the Provincial Forest Protective authorities by having all members of the various parties exert extreme care in handling camp fires, etc.

A site northwest of Seven islands, at the north end of lake Pasteur, was chosen by the Ontario Paper Company as a fire lookout, and it was suggested that it be also used as a primary geodetic station. It was expected that a tower would be required and it was understood that the parties deriving benefit therefrom would share the cost. On visiting the above-mentioned site the Geodetic engineers found that a hill about one-quarter mile northerly would fill all the requirements of both parties without incurring the heavy expenditure connected with the erection of a tower in difficult country.

Reconnaissance on the Lower Gulf of St. Lawrence Area

(J. M. Riddell)

On June 22 the engineer and his outfit landed from C.G.S. *Gulnare* at Piashti Bay, on the north shore of the gulf of St. Lawrence in longitude 63 degrees, when a boat for the work was engaged.

Some time was spent after landing in an endeavour to strengthen the existing triangulation at one point in that vicinity. This was successfully accomplished.

On July 8 the work was commenced further east, starting at the line Goynish-White, near Natashkwan. Up to August 4 eight stations had been selected, viz: Natashkwan, Post, Black, Duval, Kegashka, Forman, Musquaro and Redcliffe, carrying the triangulation as far as the Musquaro river in longitude 61 degrees. The site for a base-line near Natashkwan was also selected at this time.

From the village of Natashkwan east the country is badly broken up with low ridges, having no prominent elevations, and great tracts of open swamp with innumerable ponds and small lakes, making it very difficult to go any distance inland except along those rivers which are navigable with a canoe. This makes it necessary to establish stations near the shore wherever possible and the shore ridges are so low that it is frequently impossible to see further inland than the first ridges. Consequently, the problem is to locate stations inland that will show through gaps in the intervening ridges to the shore stations. With the exception of narrow strips on each side of the rivers the country is barren, but with occasional areas of dwarf spruce. There is some fair timber in the valleys of the Natashkwan, Kegashka, and Musquaro rivers.

East of the harbour at the mouth of the Natashkwan river there is no other harbour for twenty miles until the Kegashka river is reached, but from there on harbours for small craft are plentiful.

Secondary Triangulation in Vicinity of Sussex, N.B.

(H. P. Moulton)

At the commencement of the season some time was spent in reconnaissance for primary triangulation along Northumberland strait in the vicinity of cape Tourmentine, N.B. This work was not completed when the party was required to move to the Sussex, N.B., vicinity to lay out and observe a secondary triangulation scheme for control of mapping operations by the Topographical Survey. The area directly concerned comprised about 400 square miles, including the parishes of Sussex, Norton, Hampton, Upham, Springfield and Wickham.

The month of June and part of July was spent in a reconnaissance of the area. Smoke from forest fires greatly impeded the operations.

Late in July a tower building party was organized and three towers were built and a number of ground stations permanently marked and signals erected thereon. Near one of the towers six miles south of Norton a large deposit of graphite, apparently of very good quality, was found.

At the end of August the tower building and station preparation were completed, and the measurement of angles was commenced. Part of the work included long lines from primary triangulation stations—this work was done at night with a 10-inch, two micrometer theodolite—while the balance was composed of shorter lines on which a 7-inch, 10-second repetition theodolite was used by day. Weather conditions were extremely unfavourable owing to the mild weather which continued through the fall, with prevailing southwesterly winds which carried in fog from the bay of Fundy. Haze rising from the river valleys at night also delayed the observing.

Although the whole programme of observation was not completed, all stations were located with sufficient accuracy for topographic control. Work was discontinued December 15.

A one-ton truck and a touring car provided transportation for the party.

Direction Measurement and Tower Building Operations in Nova Scotia and New Brunswick

(J. E. R. Ross)

Direction measurement operations in Nova Scotia were confined to the territory in Cape Breton island situated along the eastern coast from a point about 20 miles north of Sydney to the extreme northern end at cape North. The reconnaissance and tower building had been completed the previous season.

This section of country is rugged, forming a table-land which rises abruptly from the shore to an elevation of about 1,600 feet above sea-level. The table-land north of Ingonish river is largely barren and scrub country, the forest growth being balsam of no commercial value; to the south the scrub gradually gives way to a mixed growth of balsam, spruce and hardwood which is being cut by the Oxford Pulp and Paper Company and gathered at Murray.

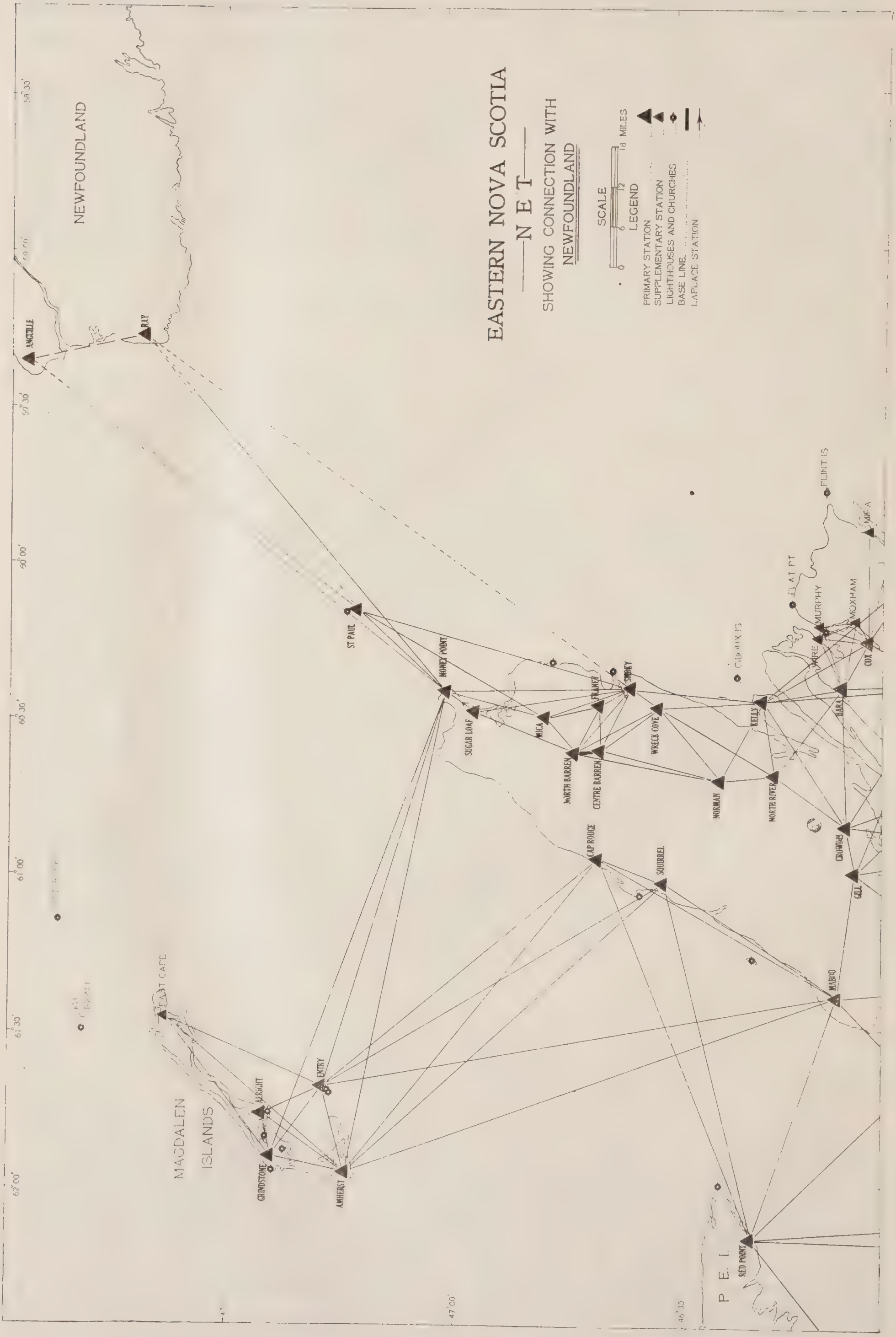
The scheme consisted of eleven stations, five along the coast and six in the interior. The interior stations were mostly accessible only on foot, and the equipment had to be man-packed as much as fifteen miles from the main camp.

Time-switches were used for a time to turn the electric signal lamps on and off, the expectation being a saving of lightkeepers. With the long distances which had to be travelled when troubles developed the innovation was a cause of delay rather than efficiency. Troubles frequently arose from wet batteries, short circuits or loose terminals due to the prevalence of rain, fog and heavy winds, and with the difficulty of transport the use of time-switches had to be abandoned.

A side of the triangulation scheme, Centre Barren to North Barren, was measured as a base-line. A preliminary calculation indicates that the accumulated error in distance from the previous base located near Amherst, N.S.—about 280 miles between bases—approximates 1 in 110,000.

This section of the triangulation was completed by the first week in August. A reduced party commenced work at cape North to complete the connection of cape North with the Magdalen islands; this was successfully carried out.

Cape North forms the junction point of a circuit of triangulation covering the Magdalen islands, the northwest shore of Cape Breton island, the Bras d'Or lake region, and the east coast of Cape Breton island. The shortest route around this circuit is 260 miles. A preliminary calculation shows the very satisfactory closing error of 4 feet in latitude and 1.5 feet in longitude, or expressed as a ratio about 1:320,000. This result is most gratifying, being the first circuit of triangulation composed entirely of the work of the Geodetic Survey of Canada which has been completely observed. It shows a very high standard of geodetic practice.



EASTERN NOVA SCOTIA
NET
SHOWING CONNECTION WITH
NEWFOUNDLAND
SCALE
0 6 12 18 MILES
LEGEND
PRIMARY STATION
SUPPLEMENTARY STATION
LIGHTHOUSES AND CHURCHES
BASE LINE
LAPLACE STATION
NEWFOUNDLAND
MAGDALEN ISLANDS
P. E. I.
ANGUILLE
RAY
ST PAUL
MONEY POINT
SUGAR LOAF
MICA
FRANCE
SMOKY
NORTH BARREN
CENTRE BARREN
WRECK COVE
NORMAN
NORTH RIVER
KELLY
MURPHY
MOXHAM
COX
FLINT IS
FLAT PT
CAP ROUGE
SQUIRREL
CROWDIS
GILL
MABOU
ENTRY
AMHERST
GRINDSTONE
ALRIGHT
EAST CAPE
RED POINT
58°30'
59°30'
60°00'
60°30'
61°00'
61°30'
62°00'
47°00'
46°30'

The connection of cape North and cape Smoky on Cape Breton island with capes Ray and Anguille, Newfoundland, using St. Paul island as a central point, was attempted, but owing to low visibility was not completed. All the work at Money point (cape North) was completed and everything at St. Paul, with the exception of the line to cape Ray. While this line is 15 miles shorter than the line from Money point to the same station, and almost in the same plane, the higher elevation of Money point, 1,350 feet, as against 550 feet for St. Paul, probably allowed the penetration of the light rays about the heavy fog banks prevalent around St. Paul and cape Ray. Heavy fogs prevail at cape Ray and the observations to and from this station will be very difficult to obtain.

Tower building and station preparation operations were divided among three areas, Newfoundland, Cape Breton island and westward in Nova Scotia proper, and on the bay of Chaleur triangulation. In Newfoundland the work consisted of the preparation of two stations, capes Ray and Anguille, necessary for the connection by triangulation with capes North and Smoky of Cape Breton island. In Cape Breton island and westward in Nova Scotia the work consisted in more permanently marking previously established stations. The reason for this re-marking has been outlined in previous reports and briefly summarized is—obliteration of the station mark due to two main causes, viz., heavy growth of scrub vegetation and destruction of mark in surface rock stations by vandals. In place of a bronze tablet in surface rock being the sole mark, fourteen stations have been re-marked with a standard monument of 3-foot base, surmounted by a 1-foot cube with a bronze tablet in top centre.

On prominent rocky points, easily distinguished as the station site, a 1-foot cube with a disk bolt has been used for two stations.

This work was completed early in July and the party transferred to the bay of Chaleur region. In this area eight towers of an average height of 45 feet were erected and three ground stations prepared.

At Blue Mountain a 40-foot steel fire-lookout tower was erected, with an inner tripod 18 feet high for the instrument. This tower is the property of the New Brunswick forest service and the expense was divided between the Forest Service and the Geodetic Survey.

Geodetic Astronomy and Standards

(F. A. McDiarmid, Supervisor of Standards)

Geodetic Astronomy.—Three of the triangulation stations of the Geodetic Survey of Canada were occupied as Laplace stations in the summer of 1923. These were Sugar Loaf in Cape Breton island, Campbellton in New Brunswick, and Chicoutimi in the Lake St. John district of Quebec.

The geodetic station at Sugar Loaf, Cape Breton, is on a hill about thirteen hundred feet above the sea, and commands a splendid view of the coast. Telegraph connection to Ottawa was established by means of the Government telegraph wire from Bay St. Lawrence to North Sydney, and the Canadian National Telegraph from North Sydney to Ottawa. Telegraph repeaters were used at Quebec and Montreal. Despite the long distance from Ottawa to Sugar Loaf, nearly fifteen hundred miles, the exchange of time signals on any night consumed only four or five minutes. Cordial and hearty co-operation is always extended by the telegraph companies in expediting the longitude work. The weather at Sugar Loaf was generally good. The first observations were made on July 13 and on the evening of July 18, five complete nights' observations had been obtained. When these observations were reduced it was found that range of differences of longitude was less than seven hundredths of a second of time. The latitude was determined from twenty pairs of stars observed by the Talcott method.

Azimuth observations were made on the line Sugar Loaf to Money point, a distance of about six miles. Observations were secured on two nights, using twenty-three positions of the horizontal circle.

The Campbellton station is on the hill called "Sugar Loaf," just behind the town of Campbellton, commanding a splendid view of the whole country. Fairly good weather prevailed; the time observations were commenced on August 3 and completed on August 10. During this period two good nights were lost through a break in the telegraph loop connecting the observing station with the main telegraph line.

The azimuth of the line joining Campbellton and Mann geodetic points was determined from two nights' observations. In all thirty-two azimuth sets were made, sixteen on each night. The means of the two nights agreed within five hundredths of a second of arc.

The Chicoutimi geodetic point is about two miles west of the town of Chicoutimi on a rocky hill along the macadamized road from Chicoutimi to Jonquiere. Five nights longitude, fifteen pairs of latitude stars and the azimuth of the line joining the stations Chicoutimi to Jonquiere were secured between August 22 and August 30. Here again the azimuth determination depends on the mean of thirty-two positions of the horizontal circle.

In order to get the outfit to these several stations it was necessary to "pack" the various boxes, tents, etc., distances ranging from one-half to two miles. The large Cooke transit used in the field longitude work without its packing cases weighs in the neighbourhood of three hundred pounds. To pack the outfit on such occasions is a dangerous and laborious task, as the trails to the hills are rough and steep.

In addition to the field observations for longitudes, personal equation observations were made before and after the season's work. These observations show a personal equation of nearly a tenth of a second of time between the clock correction as determined by the field observer with the Cooke transit, and that given by the clock curve of the Riefler clock of the Dominion Observatory.

Through the kindness of the Director of the United States Coast and Geodetic Survey, one of the Bamberg broken type transits of the United States Coast and Geodetic Survey was loaned to the Geodetic Survey for experimental purposes. A long series of tests for personal equation was made and the mean value of the personal equation between the clock correction as deduced from the Bamberg observations and that from the Riefler clock curve was only fourteen ten-thousandths of a second of time. The theory of this instrument is discussed in a separate publication now in course of preparation.

Standards.—The work done in the Standards building during the year 1923-24 consisted in the determination of the lengths of the several fifty metre invar tapes of the Survey, and in the graduating and standardizing the new precise level rods.

The five tapes were standardized from the standard nickel bar No. 10239 in May, September and October, before and after measuring each of two base-lines. These tapes are now well aged, and yet they are still changing in length relative to one another, and also to the standard bar. This shows the vital necessity of standardizing before and after measuring every base-line.

The new invar precise level rods made from invar strips fastened to pine rods were used during the past summer and gave complete satisfaction. These invar strips were first graduated and the rods were then painted and subdivided. The graduations at 3, 6 and 9 feet marks were then standardized just before taken to the field. A standardization after returning from the field showed that no changes in length had occurred. When the rods were first made, it was feared they might warp and cause changes in length. This fear fortunately was not well founded and the rods in every way behaved well.

Measurement of Two Primary Base Lines

(K. H. Robb)

The Barrens Base Line, Cape Breton Island.—The engineer left Ottawa on June 17, and a temporary camp near Ingonish, Cape Breton island, was reached and six men hired by June 25. From here to the base-line, a distance of about seven miles with a difference of elevation of 1,743 feet, supplies and camp equipment had to be packed by horse and men. From the settlement the trail followed the Clyburn brook to the foot of a steep hill called Indian Rising, where a climb of about 1,200 feet in one and a quarter miles was made to the Barrens. During the winter snow had blown over the side of the mountain and lodged on the north slope to the depth of sixty or seventy feet, and there were several feet of snow still on the ground in the middle of August. The Barrens base-line is one of the sides of the primary triangulation tying between stations Centre Barren and North Barren. Clearing the line of timber was commenced at Centre Barren station on July 2 and by the end of the month the whole line to North Barren had been cleared and posted. The country lying between these two stations was partly covered by heavy spruce underbrush and trees. Owing to the heavy snow, high winds and the exposed nature of the country, trees that would ordinarily stand twelve feet high were lying flat on the ground. Clearing the line was thus very difficult and often trees would have to be cut several times before they could be cleared away from the entanglement. Suitable posts were hard to obtain. They were cut around the foot of the hills where the trees were sheltered, and carried in some cases considerable distances to the line.

Measuring was commenced on August 1 and finished August 4. Ideal weather (which is essential to good results) prevailed during this period. The same procedure was carried on as in the measurement of previous bases, as has been described in previous reports. The length of the base corrected for grade and height above sea-level is 5952.863894 metres.

Levels run over the top of the posts to determine the grade corrections and connected with sea-level at Ingonish, twelve miles distant, show an elevation of 1,743 feet at Centre Barren. Levelling was commenced on August 6 by a party of four men, the remainder of the party packed out the camp equipment to Franey where a temporary camp was established. The whole work was completed on August 15, when camp was broken up, party disbanded and outfit shipped.

Bay of Chaleur Base Line.—The engineer proceeded direct from Ingonish to Charlo, where camp was established on August 17 on the right of way of the Canadian National railway, about one-quarter of a mile east of Charlo station. The base-line selected was for the most part along the right of way of the railroad. A deflection of about 15 degrees occurs nine hundred and twenty-two metres from one end and one of about five degrees near the other end. Fifty-foot towers had been built at both ends of the base by the building party.

The work of posting and putting in concrete piers at the deflection points was soon completed and measuring commenced on September 12. The whole work of measuring and levelling was completed on September 19, when the party was disbanded and the outfit shipped to Ottawa.

The deflection angles at east base, west base and the two intermediate points were measured with a twelve-inch theodolite, and the levels were tied to one of the Geodetic Survey bench-marks.

LIST OF PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA

Publication No. 1—Precise Levelling—Certain lines in Quebec, Ontario and British Columbia.
Publication No. 2.—Adjustment of Geodetic Triangulation in the Provinces of Ontario and Quebec.
Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.
Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec.
Publication No. 5—Field instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulation.
Publication No. 6—(Withdrawn from publication, as levelling contained is republished in Bulletins.)
Publication No. 7—Geodetic Position Evaluation.
Publication No. 8—Field instructions for Precise Levelling.
Publication No. 9—The Making of Topographical Maps of Cities and Towns, the First Step in Town Planning.
Publication No. 10—Instructions for Building Triangulation Towers.
Instructions to Lightkeepers; Use of Electric Signal Lamps being Appendix No. 4 to Publication No. 5.
The Geodetic Survey of Canada; Operations, April 1, 1912, to March 31, 1922—Publications of the International Geodetic and Geophysical Union, 1922.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1918.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1919.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1920.
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1921
Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1922.
Annual Report of the Director of the Geodetic Survey of Canada for the fiscal year ending March 31, 1923.

Precise Levelling Bulletins

Bulletin A—
Vancouver, B.C. and adjacent district—as far east as Mission, Matsqui and Huntingdon.
Bulletin B—
Abbotsford to Resplendent, B.C.
Spence Bridge to Brodie, B.C.
Mission to Hope, B.C.
Bulletin C—
Saskatoon, Sask., to Prince George, B.C.
Prince Rupert to Prince George, B.C.
Bulletin D—
Calgary, Alta., to Kamloops, B.C.
Revelstoke to Arrowhead, B.C.
Sicamous to Okanagan Landing, B.C.
Bulletin E—
Kipp, Alta., to Golden, B.C.
Bull River to Kootenay Landing, B.C.
Bulletin F—
Calgary to Lethbridge, Alta.
Calgary to Tofield, Alta.
Camrose to Wetaskiwin, Alta.
Bulletin G—
Moose Jaw, Sask,, to Coutts, Alta.
Swift Current, Sask., to International Boundary.
Bulletin H—
Irricana to Medicine Hat, Alta.
Bassano, Alta., to Swift Current, Sask.
Empress to Compeer, Alta.
Kerrobert to Unity, Sask.
Bulletin I—
Stephen, Minn., to Regina, Sask.
Regina to Prince Albert, Sask.

Bulletin J—
Napinka to Neepawa, Man.
Minnedosa, Man., to Regina, Sask.
Yorkton to Saskatoon, Sask.
Colonsay to Prince Albert, Sask.
Lanigan, Sask., to Brandon, Man.
Bulletin K—
Emerson, Man., to Port Arthur, Ont.
Sprague to Neepawa, Man.
Portage-la-Prairie to Plum Coulee, Man.
Bulletin L—
Winnipeg, Man., to Kenora, Ont.
Winnipeg to Victoria Beach, Man.
Bulletin M—
Rennie, Man., to Armstrong, Ont.
Superior Junction to Rowan, Ont.
Bulletin N—
Sudbury to Cochrane, Ont.
Armstrong to Cochrane, Ont.

Copies of the above publications may be obtained by applying to the Director of the Geodetic Survey of Canada, Ottawa.

Respectfully submitted,

NOEL OGILVIE,
Director.

To W. W. Cory, Esq., C.M.G.,
Deputy Minister of the Interior,
Ottawa.

INDEX


Department of the Interior
GEODETIC SURVEY OF CANADA
MAP SHOWING
PROGRESS OF TRIANGULATION
AND
PRECISE LEVELLING
TO MARCH 31, 1924
NOEL OGILVIE, DIRECTOR
Natural Scale 1/7,603,200
Scale: 100 miles to one inch
LEGEND
TRIANGULATION COMPLETED
TRIANGULATION BEGUN
PRECISE LEVELLING
Victoria Island
Southampton I.
HUDSON BAY
NORTHWEST TERRITORIES
DISTRICT OF MACKENZIE
YUKON
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
PACIFIC OCEAN
ATLANTIC OCEAN
GREAT BEAR LAKE
GREAT SLAVE LAKE
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
GULF OF ST. LAWRENCE